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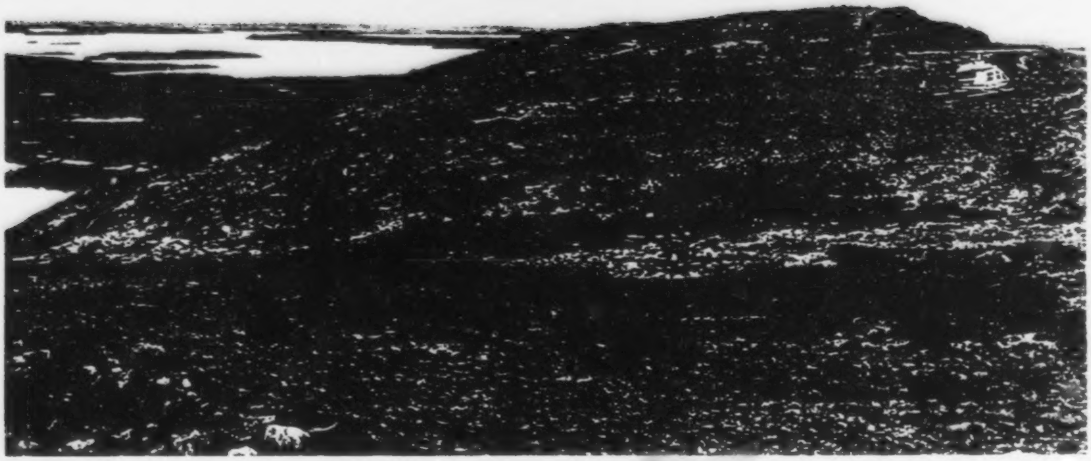
GEOLOGY OF THE NORTHEASTERN SMALLWOOD RESERVOIR (NTS MAP AREA 13L/SW), LABRADOR



G.A.G. Nunn

Report 93-3

St. John's, Newfoundland
1993

COVER

The Buttress (Looking northeastward across Fraser Lake). Petscapiskau Group metasedimentary paragneiss in the aureole of the Michikamau Intrusion forming the western, up-ice end of a crag-and-tail – ice flow was from left to right.

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The amphibolite (subunit 1a, approximately 30 percent) is dark-green- or black-weathering, dark grey, fine to medium grained, homogeneous or layered and rarely contains a plagioclase spotting (A), and, locally, quartz veining and patches and streaks of epidotization are present (A^e). The metasedimentary rocks (subunit 1d, approximately 50 percent) consist of plagioclase-porphyritic tuffs and minor pelite and thinly layered, siliceous, feldspathic or tremolite-bearing metasedimentary rock (M). Dark-grey, homogeneous, plagioclase–biotite dykes (subunit 2f, first set – see text) are subparallel to the paragneiss layering but in detail transgress the layering in both the amphibolite and the metasedimentary rock (D, approximately 5 percent). Granite (subunit 2g) preferentially occurs in sheets (G, approximately 15 percent) at amphibolite–metasedimentary contacts, or as thin stringers and veins in either lithotype, but also cuts out or cuts across the thicker, less ductile amphibolite layers with sharp, angular relationships.

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NOTES TO ASSIST THE READER

Grid references refer to the Universal Transverse Mercator grid system zone 20 U, one hundred kilometre squares MQ and MR and are given in eight figures (±10 m). They are subject to inaccuracies in the original plotting of the locality and, in this report, to errors by the author in the making of the base map.

Granitoid rock terminology follows IUGS recommendations (Streckeisen, A.; Earth Science Reviews, Volume 12, pages 1-33, 1976) and the acid to intermediate volcanic rock terminology (Unit 8) has been adapted to fit the same fields.

Modifiers preceding the root term occur in order of increasing abundance, e.g., hornblende–biotite–quartz monzonite contains more biotite than hornblende. However, rocks described by a list of mineral species are given in decreasing order of abundance, e.g., the same quartz monzonite, if from Unit 9, would likely be written potassium feldspar–plagioclase–quartz–biotite–hornblende + accessory minerals. In the report most metamorphic assemblages are written this way. Mineral lists separated by plus signs imply no particular order of abundance.

Some subunit descriptions in this report do not have a Petrography section.

ABSTRACT

The study area spans the major lithotectonic boundary between rocks of the Rae Province to the north and the Labrador Orogen to the south.

Rae Province rocks consist of an Archean, pillow-lava dominated supracrustal sequence (including pelite, psammite, tuffs and gabbro sills), which is intruded by a mainly synorogenic Late Archean tonalite–granodiorite batholith (the Sail Lake intrusive suite) and a gabbro–diorite–granite complex of uncertain, but pre-Middle Proterozoic, age. The association of the first two defines the Orma Domain and most rocks in the domain now consist of amphibolite–facies metasediment, metavolcanic rocks and orthogneiss. The batholith and the synplutonic orogeny have yielded ages ranging from 2690 to 2660 Ma, and the isotopic data indicate negligible Hudsonian reworking together with a Middle Proterozoic lead-loss event for the Orma Domain. Two metasedimentary units of unknown affinity are also present; they are a migmatitic arkosic unit and the Petscapiskau Group, each of which may either be equivalent to the Archean supracrustal rocks or be a cover sequence to the orthogneiss. The Petscapiskau Group is a succession of pelite, pillow lava, psammite and minor conglomerate, and, mostly, is in the greenschist facies. It contains a major, bedding-parallel (pre-Labrador orogen) foliation.

The Labrador Orogen (late Early Proterozoic) is dominated by K-feldspar-megacrystic quartz monzonite and quartz syenite phases of the North Pole Brook Intrusive Suite, which is a part of the Trans-Labrador batholith. Granite, quartz monzodiorite and gabbro also occur and the plutonic rocks contain pendants of the Mackenzie Lake group, a coeval andesite–continental clastic sequence. Locally, these rocks contain a weak synplutonic foliation.

The boundary between the Rae Province rocks and the Labrador Orogen is intrusive and/or tectonic and satellite stocks of the batholith occur in the Orma Domain. Contact metamorphism of the Petscapiskau Group by the North Pole Brook Intrusive Suite demonstrates that this major boundary, between Rae Province rocks and distinctive, high-grade, paragneiss terranes (present south of the batholith throughout Labrador), was established at the time of the Labradorian Orogeny in the late Early Proterozoic and is unrelated to the Grenvillian Orogeny.

The Sail Lake intrusive suite and the Petscapiskau Group are intruded by the Michikamau Intrusion, an Elsonian (early Middle Proterozoic) anorthositic pluton, which generated a well-developed thermal aureole in the metasediments. In, or close to, the map area, Rae Province, Labradorian and Elsonian rocks are unconformably overlain by the Seal Lake Group and equivalent rocks. This group is a mid-Middle Proterozoic sequence of continental red beds, which probably include some stromatolitic rocks, and the unconformable relationship is of regional extent. The Seal Lake Group may have been deposited across the whole of central Labrador.

The southern two-thirds of the study area lie within the Grenville Front Tectonic Zone, a zone of gradually southward-increasing tectonic intensity relating to the Grenville Orogeny and bounded to the north by the Grenville Front. North of the Grenville Front, Rae Province rocks and the Seal Lake Group are undeformed by Grenvillian tectonism. South of the front, previously undeformed cover rocks (Seal Lake Group) range from gently warped in the north to northward-verging, overturned folds and associated cleavage farther south, whereas the basement Orma Domain, the Petscapiskau Group and the Michikamau Intrusion contain only brittle structures of this age. The North Pole Brook Intrusive Suite contains anastomosing shear zones and static alteration developed in subgreenschist- to greenschist-facies conditions and south of the study area Grenvillian greenschist facies effects are penetrative.

A set of north-northwest-trending faults of post-Grenvillian age, having downthrows to the east, is responsible for preservation of the Seal Lake Group in half graben. Elsewhere, erosion of the Seal Lake Group has, approximately, exhumed the mid-Middle Proterozoic land surface.

Surficial deposits are widespread and consist mostly of till, outwash and eskers. A raised beach on the shore of Michikamau Lake indicates the former presence of an earlier, higher, proglacial lake water-level stand than lakes, Maclean and Naskaupi, in the George River catchment basin to the north of the study area.

The best economic prospect is a large area, 1.25 by 0.75 km, of gossan patches at the edge of the Michikamau Intrusion that exhibits pyrrhotite–chalcopyrite mineralization.

INTRODUCTION

LOCATION AND ACCESS

The study area comprises NTS map areas 13L/3, 4, 5 and 6, a total area of approximately 3600 km^2 (Figure 1). It is bounded by longitudes 63°00' and 64°00' west and latitudes 54°00' and 54°30' north. The map area is located in and around the northeastern part of the Smallwood Reservoir and lies to the east of Michikamau Lake (Figure 2). Michikamau Lake is centred 65 km north of Churchill Falls in west-central Labrador and is one of the main bodies of water within the reservoir system.

The reservoir provides almost continuous lakeshore access throughout the south, central and southwestern parts of the map area. The area is accessed either by float-plane charter from Labrador City or Goose Bay, or by a service road from Churchill Falls (leading northeastward to the dyke structures along the eastern edge of the reservoir), or by water from other parts of the reservoir (Figure 2). The service road also gives access to most of the area east of the reservoir, and portions of the north part of the map area are accessible by float plane to Fraser Lake. Parts of the northwest, north and northeast are best visited by helicopter, but can be reached by long traverses from the nearest road or lakeshore localities.

Churchill Falls may be reached (Figure 2) by using a scheduled air service from Wabush/Labrador City or Goose Bay and by road from Labrador City (240 km), from Esker, on the Quebec North Shore and Labrador (QNS&L) railway, 180 km to the west, or from Goose Bay (290 km). The overland routes from Labrador City, Goose Bay and Esker are all-season gravel roads. The service road from Churchill Falls to the reservoir is a summer-only road that requires annual repair due to spring-runoff washouts; this road may not be open until late July and is closed again by the autumn snows.

PREVIOUS WORK

The first geological reconnaissance in the Michikamau Lake area was made in 1894 (Low, 1896, 1897). Low *(op. cit.)* recognized granitoid rocks (Unit 9)[*], anorthosite (Unit 10) and blue-grey limestone (subdivision $11b^4$?) in the present map area, and red beds (equivalents of subdivision $11b^1$) and stromatolitic limestone (equivalents of subdivision $11b^4$) immediately to the south.

In the earlier part of this century, the Labrador Mining and Exploration Company (LM&E) lease extended throughout western Labrador as far east as 63°W, which is also the eastern margin of the present study. In the 1940's, the company conducted geophysical work in the Windbound Lake area (reported *in* Thompson, 1953) with follow-up geological reconnaissance (Thompson, 1949, 1953).

The map area was included in an aerial photographic study of the glacial features of Ungava (Douglas and Drummond, 1953) and in a physiographic classification of the Labrador–Ungava peninsula (Douglas and Drummond, 1955).

Further exploration for the LM&E in the 1950's involved an airborne scintillometer and electromagnetic survey (Sutherland and McPherson, 1957) and follow-up geological reconnaissance (Findlay, 1957; Sanderson and Jones, 1958).

Mann (1959) and Brummer and Mann (1961) mapped and described the stratigraphy and economic geology of the Seal Lake Group (subunit 11a) to the east of the map area.

Potassium–argon dates were reported for granitoid rock (Unit 9; Lowdon *et al.*, 1963, p. 116) and, 18 km west of the map area, for anorthosite (Unit 10; Emslie, 1964a). As a result of a regional-mapping program for the Geological Survey of Canada, Emslie (1964b) produced a 1:253 440-scale map of the study area and the region to the north and described the petrology and petrography of the Michikamau anorthositic Intrusion (Emslie, 1965; Unit 10). Potassium–Argon dates for the chilled margin of the Michikamau anorthositic Intrusion and for its aureole (parts of Unit 5) were given in Wanless *et al.* (1965, p. 113, 114), and for basaltic tuff (equivalents of subdivision $11a^5$) 8 km north of the map area in Wanless *et al.* (1967, p. 118, 119). A paleomagnetic pole position for the Michikamau anorthositic Intrusion was determined by Murthy *et al.* (1968). Emslie (1969, 1970) then produced the most complete descriptions of Unit 10, and formally renamed it the Michikamau Intrusion. While describing the Michikamau Intrusion, Emslie (1965, 1970, and *in* Wanless *et al.*, 1965) also discussed the petrology and age of Unit 5, which he named the Petscapiskau Group (Emslie, 1970).

In 1970, Geoterrex conducted an airborne geophysical exploration for Brinex (reported by Barton and Barton, 1971), which was followed up by Barton and Barton (*ibid*), and in 1971, the Geological Survey of Canada flew an airborne gamma-ray spectrometry transect into the area from the south (Darnley *et al.*, 1972). Follow-up paleomagnetic petrology was done on the Michikamau Intrusion (Murthy *et al.*, 1971) and Wanless *et al.* (1972, p. 85, 86) reported a K–Ar date on a granitoid rock (Unit 9) from 10 km south of the map area.

Brief descriptions of the Petscapiskau Group and the Michikamau Intrusion were given by Emslie *et al.* (1972), and additional dates on these two units are recorded by Wanless *et al.* (1974, p. 52, 53) and on the latter by Krogh and Davis (1973).

Vanderveer (1973) produced a classification of surficial deposits for the Michikamau Lake area, and a classification of surficial deposits for the map area is included in that presented by Fulton *et al.* (1980) for NTS map area 13L.

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[*] Units refer to this study unless noted otherwise.

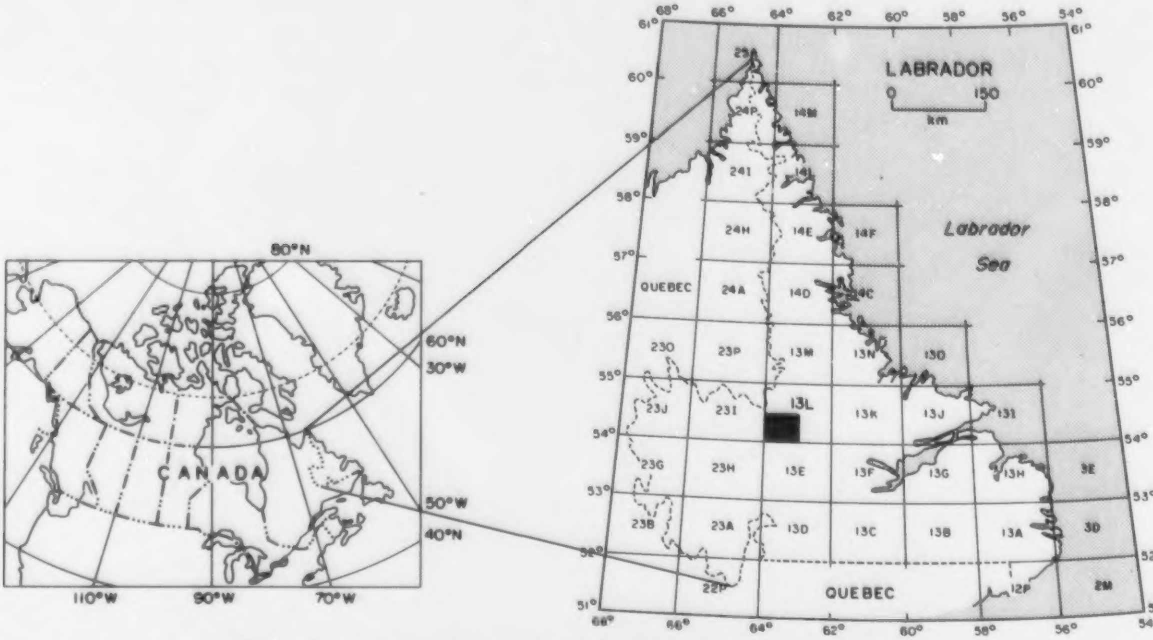


Figure 1. *Location of the northeastern Smallwood Reservoir map area.*

Greene (1972) compiled a 1:1 000 000-scale map of the geology of Labrador, and in a companion report (Greene, 1974) discussed potential stratigraphic correlations of supracrustal units in central Labrador (including Units 1, 5, 8 and 11). These correlations were also considered by Smyth *et al.* (1975, 1978).

Further paleomagnetic work on the Michikamau Intrusion was done by Emslie *et al.* (1976), and a discussion of the ages and petrology of the intrusion is presented by Emslie (1978a), who also discusses the Petscapiskau Group and Unit 8 (Emslie, *op. cit.*, and Emslie, *in* Wanless and Loveridge, 1978, p. 44-46 and Wanless *et al.*, 1978, p. 52).

A part of NTS map area 13L/3 was included by Nunn (1981) in a report on mapping immediately south of the map area, and the present study area is described in a preliminary report by Nunn and Noel (1982). Age determinations (Brooks, 1982, 1983; Krogh, 1983, 1985) were made on the granitoid rocks [Unit 9; named the North Pole Brook Intrusive Suite, east of the map area, by Thomas and Hibbs (1980)], within and to the south of the map area, and on Unit 8 (Krogh, 1985). The ages of Unit 8, the North Pole Brook Intrusive Suite and the Michikamau Intrusion were summarized as a part of a paper by Nunn *et al.* (1985), at which time Unit 8 became informally known as the Mackenzie Lake group (*ibid.*). These data contributed to regional syntheses of the geology of west-central Labrador (Thomas *et al.*, 1985, 1986) and to tectonic classifications of the Grenville Province in Labrador (Rivers and Nunn, 1985; Rivers and Chown, 1986; Wardle *et al.*, 1986).

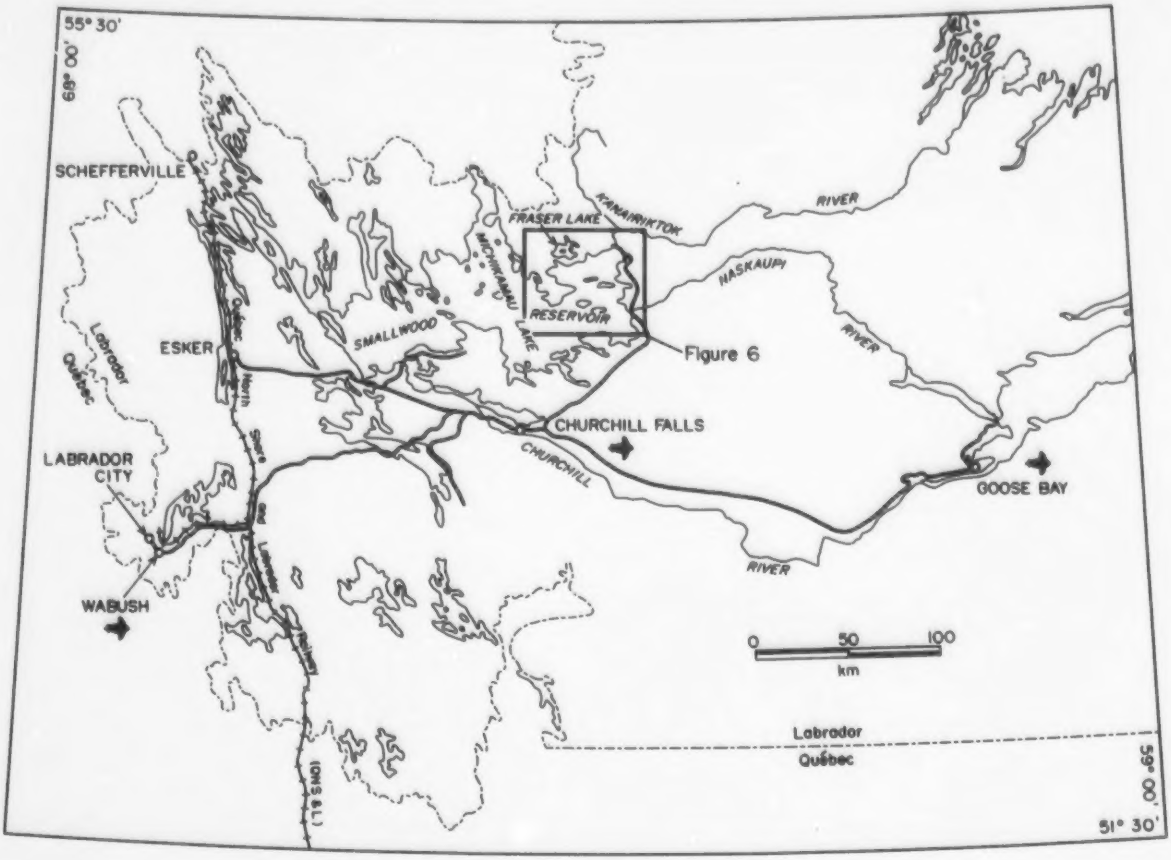
Klassen and Bolduc (1984) studied glacial striation directions south of the map area and Bolduc (1985) studied eskers in the same area to the south. A general deglaciation history of the Labrador–Ungava area is given by Vincent (1989).

Uranium–lead dates from tonalitic orthogneiss (Unit 2, named the Sail Lake intrusive suite in this report) are reported by Nunn *et al.* (1990) and these data are included on a preliminary compilation of the geology of the map area by Nunn (1990).

PRESENT INVESTIGATION

This study forms the second and northern part of a two-year mapping project carried out under the Canada–Newfoundland Mineral Development Subsidiary Agreement (1976-1982). The first part of the project has been reported by Nunn (1981, 1982) as have preliminary results on the present study area (Nunn and Noel, 1982).

The principal aims of the project are to expand the geological database for central Labrador, to describe the various supracrustal sequences and their relationship to granitoid and gneissic rocks in the map area, and to elucidate the mineral potential of the supracrustal sequences. The first objective was achieved by 1:100 000-scale mapping in conjunction with other projects at the Newfoundland Department of Mines and Energy headed by Wardle (1985) and Thomas (1993). The other two objectives, which were conceived because of potential correlations with, and extension of, the Central Mineral Belt of Labrador (Gandhi *et al.*, 1969; Smyth *et al.*, 1975, 1978; Ryan, 1984) that lies to the east of the map area (Beavan, 1958), are met, in part, by this report.


55° 30'
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SCHEFFERVILLE
FRASER LAKE
KANAIRIKTOK
RIVER
NASKAUPI
RIVER
MICHIKAMAU
LAKE
RESERVOIR
SMALLWOOD
Figure 6
ESKER
Labrador
Québec
Quebec
North
Shore
and
Labrador
Railway
(QNS&L)
CHURCHILL FALLS
CHURCHILL
RIVER
LABRADOR CITY
GOOSE BAY
WABUSH
0
50
100
km
Labrador
Québec
59° 00'
51° 30'

Figure 2. *Access map for the Smallwood Reservoir area, western Labrador.*

Flooding of the Smallwood Reservoir began in 1971 and was completed in the map area in 1973. Consequently, published topographic base maps were of little use and field data were plotted on 1:40 000-scale aerial photographs, which were produced for the Churchill Falls (Labrador) Corporation (CFLCo), supplemented by blueline reproductions of 1:50 000-scale airphoto mosaics of the reservoir area. Base maps for the area were made by hand using the mosaics to correct NTS maps published at 1:50 000 scale (NTS 13L/3, 4 and 5; Mines and Technical Surveys, 1960) and 1:250 000 scale (NTS 13L; Energy, Mines and Resources, 1968), and are subject to errors of detail in both shape and position. Subsequently, the base map for the NTS map area 13L/6 was replaced by one of the new series of metric 1:50 000-scale NTS maps (Energy, Mines and Resources, 1984). The base maps were photographically reduced and redrafted for publication at 1:100 000 scale. These maps assume a full reservoir; actual lakeshore positions vary considerably, both seasonally and from year to year.

Mapping of the lakeshore was undertaken using a Zodiac boat, and ground traverses were carried out from the road and the lakeshore in most areas of better exposure. Data for the northwest and west of the map area were compiled from Emslie (1970). The remainder of the area was reconnoitred or mapped using helicopter access.

PHYSIOGRAPHY

The map area is part of an undulating plateau that lies astride the watersheds between drainage northward to Ungava Bay via the George River, east to the Labrador Sea via the Kanairiktok and Naskaupi rivers, and west and south to the Labrador Sea via the Churchill River (Figure 3). The plateau represents a modified erosion surface of regional extent. It was named the Michikamau Plateau by Douglas and Drummond (1955) and lies at the northeast corner of Henderson's (1959) Lake Plateau of western Labrador. In the map area, the plateau varies from an average height of about 540 m in the north to about 500 m in the south. Many residual hills of a former, higher erosion surface occur throughout the map area, particularly in the watershed areas, and reach up to 620 m.

The postglacial watershed, between flow to the Labrador Sea via the Churchill River and that more directly to the east, lay to the south and west of the map area with an

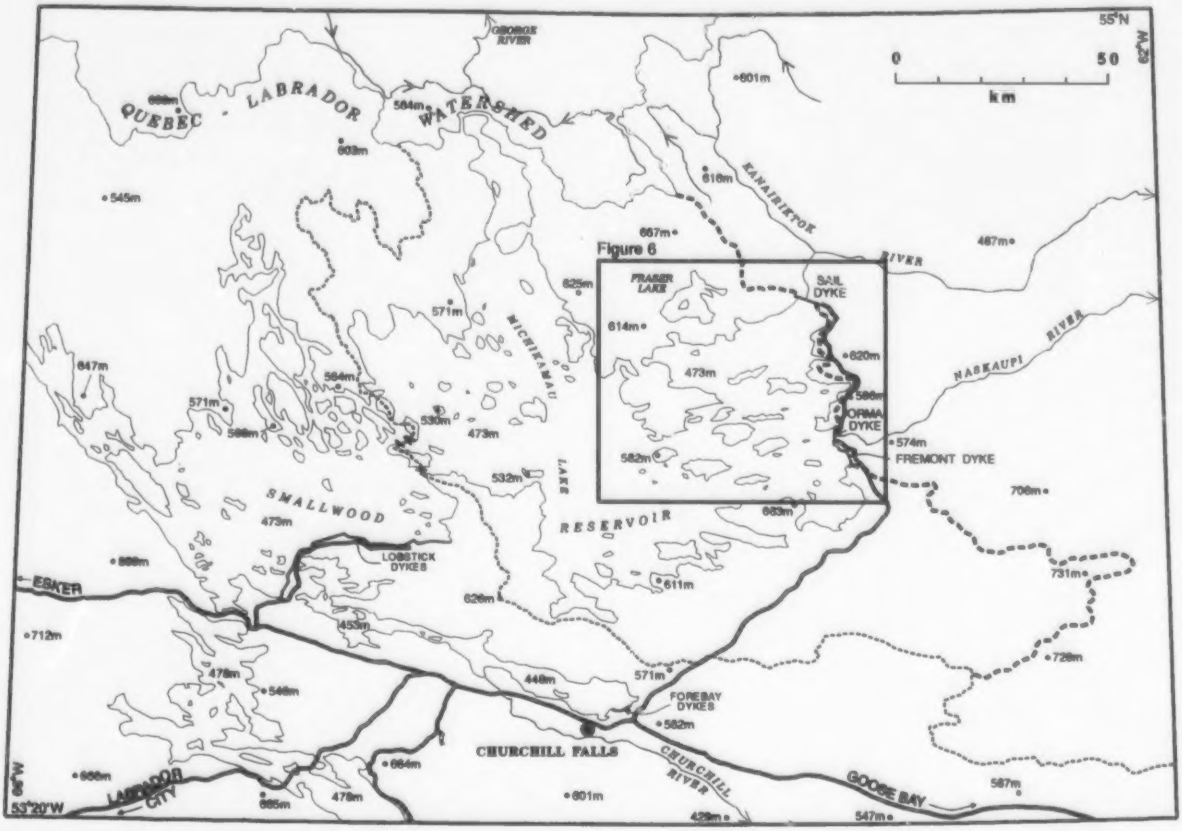

GEORGE RIVER
QUEBEC - LABRADOR WATERSHED
608m
603m
545m
584m
601m
616m
KANAIRIKTOK RIVER
667m
487m
Figure 6
FRASER LAKE
SAIL DYKE
625m
614m
571m
MICHIKAMAU LAKE
620m
473m
NASKAUPI RIVER
586m
ORMA DYKE
574m
FREMONT DYKE
582m
647m
584m
571m
568m
530m
473m
532m
706m
SMALLWOOD RESERVOIR
473m
663m
LOBSTICK DYKES
608m
ESKER
611m
731m
626m
712m
453m
728m
478m
546m
448m
571m
FOREBAY DYKES
582m
CHURCHILL FALLS
664m
CHURCHILL RIVER
666m
LABRADOR CITY
665m
478m
601m
428m
GOOSE BAY
547m
587m
55°N
63°W
66°W
53°20'W
0
50
km

Figure 3. *Changes in position of the watershed between easterly directed flow, principally via the Naskaupi and Kanairiktok rivers, and that via the Churchill River resulting from formation of the Smallwood Reservoir. Heights without point locations refer to approximate water levels in the reservoir. Pre-flooding watershed* ········ *; Cols in pre-flooding watershed, ca. 465 m* ··+··· *; Post-flooding watershed* - - - -

approximately north-northwesterly orientation and cols at about 465 m. Following the flooding of the reservoir, a man-made watershed has been formed in the east of the map area with a northerly orientation. The cols in this watershed, which connects the higher hills in the east of the map area, are the dykes that hold back the reservoir waters, and are several metres above full-reservoir water level. The maximum water-level elevation occurs at 473 m above sea level in this part of the reservoir.

In the area surrounding the reservoir, much of the relief is gentle. The hills have been rounded by glacial erosion and the valleys and basins partly infilled by glacial deposition; only in the northeast of the map area has rejuvenation resulted in steep-sided, incised river valleys. Relief between hill top and valley bottom in the area averages about 110 m and has a normal maximum of about 150 m, except in the northeast where the Kanairiktok River occupies a gorge up to 180 m deep.

The Michikamau Plateau is part of a broad region of 'drumlinized till' (Douglas and Drummond, 1955), and most of the map area is covered by till. In the southern two-thirds of the map area, the broad east–west-oriented valleys are filled with rib-moraine complexes, whereas the intervening hills are covered with basal till. North of here and in the centre of the east of the map area, the topography is characterized by large, flat areas of string bog punctuated by low, tree-covered mounds (hummocky terrain) and linear ridges (glacial fluting), both of which are composed of till, or by an undulating, sparsely vegetated sand plain that is studded by kettle holes and underlain by outwash. Eskers form prominent sinuous ridges throughout the map area.

The map area lies just south of the present limit of continuous permafrost (Vincent, 1989) and is about 200 km south of the very irregular tree line in the Quebec–Labrador watershed area. Most of the tree cover consists of spruce; although the steeper hillslopes and more rugged terrain are characterized by mixed spruce and fir. Areas of sandy till and outwash have a less dense tree cover.

Despite the relatively pervasive cover of surficial deposits, some parts of the area contain good bedrock exposure. In the west, these occur in areas underlain by a belt of supracrustal rocks in the thermal aureole of the

Michikamau Intrusion (part of the Petscapiskau Group, Unit 5), in much of the adjacent area underlain by leucotroctolite and anorthositic rocks of the Michikamau Intrusion itself (Unit 10), and along the lakeshore of islands in Michikamau Lake underlain by granitoid rocks (North Pole Brook Intrusive Suite, subunit 9c). In the east of the map area, a belt of generally good exposure, 3 to 8 km wide, lies adjacent to the edge of the reservoir and is largely underlain by supracrustal rocks (Unit 1), granitoid orthogneiss (Unit 2) and granite (subunit 3c). Seal Lake Group red beds (subunit 11a), in the northeast, are well exposed in the walls of river gorges. In the reservoir, lakeshore bedrock outcrop is good where the flooded area is covered by a thin till veneer, but this is rare.

GENERAL GEOLOGY

INTRODUCTION

Geotectonic Setting and Regional Rock Associations

The map area lies astride the boundary between two structural provinces that are juxtaposed in central Labrador (Figure 4). The older of the two, the Churchill Province, lies to the north and is defined as those areas that underwent the Hudsonian Orogeny (ca. 1880 to 1780 Ma) as their last major dynamothermal event (Stockwell, 1973). The younger Grenville Province, to the south, underwent its last major tectonic and metamorphic event during the Grenvillian Orogeny (ca. 1100 to 980 Ma; Stockwell, *op. cit.*).

The eastern Churchill Province of Quebec and Labrador consists of three divisions (Wardle *et al.*, 1990). These are known, from west to east, as the New Quebec Orogen, the Rae Province and the Torngat Orogen (Figure 4; Hoffman, 1988, 1989). The New Quebec Orogen is composed of a Lower Proterozoic supracrustal sequence of metasedimentary, metavolcanic and gabbroic rocks (Dimroth *et al.*, 1970; Wardle and Bailey, 1981), including rare klippen and tectonic inliers of basement gneiss. The supracrustal package is called the Labrador Trough (e.g., Fahrig, 1957) and these rocks vary from greenschist to amphibolite facies in metamorphic grade. They have been regarded as a passive-margin sequence (e.g., Dimroth, 1970, 1972; Wardle and Bailey, 1981) or a foredeep succession (Hoffman, 1987), and represent a relatively high level in an orogen. The Torngat Orogen consists of Lower Proterozoic supracrustal and granitoid rocks along with Archean gneisses that were reworked during the Hudsonian Orogeny, all of which are mostly in the upper amphibolite or granulite facies. Many of the granitoid rocks are syntectonic (Hudsonian), orthopyroxene-bearing plutonic complexes and clearly represent deeply eroded levels of an orogen (Wardle *et al.*, 1990; Ryan, 1990). Between the two orogens is the Rae Province, which is dominated by Hudsonian-reworked Archean gneisses. Lesser amounts of Lower Proterozoic, syn- to late-tectonic, granitoid plutonic rocks, mainly in linear welts, and infolded layers of Lower Proterozoic supracrustal rocks, along with rare pretectonic plutonic and volcanic rocks, are also present. The degree of Hudsonian reworking of the Archean gneisses throughout the Churchill Province varies [illegible] minimal (Nunn *et al.*, 1990) to major (Ryan, 1990) and [illegible] superimposed (Hudsonian) metamorphic grade ranges up to granulite facies. The Rae Province may, in part, represent levels of intermediate erosion between the flanking orogens.

The Rae Province forms the hinterland to the New Quebec and Torngat orogens. The forelands to these orogens lie at the margins of the Superior Province in the west and the Nain Province in the east (Figure 4); these two provinces are cratonic nuclei that were last stabilized during the Late Archean. The Archean cratonic nuclei and the juvenile Lower Proterozoic crustal material were aggregated and stabilized during the Hudsonian Orogeny to form the proto-Laurentian Shield. Tectonic models for the formation of proto-Laurentia have most recently been developed by Hoffman (1988, 1989, 1990a), and, more specifically with reference to the Labrador–Ungava region, also by Hoffman (1987, 1990b).

The Rae and Nain provinces and the Torngat Orogen have been intruded by Middle Proterozoic 'anorogenic' plutonic complexes (Emslie, 1978a,b), mainly granitoid and anorthositic rocks, and these and the older rocks are unconformably overlain by later Middle Proterozoic continental clastic rocks.

The Grenville Province in central Labrador consists of two major lithotectonic associations (Figure 4); in the north, a 10- to 50-km-wide marginal zone and, in the south, rocks that belong to the Labrador Orogen (Nunn *et al.*, 1984, 1985; Thomas *et al.*, 1985). The marginal zone contains rocks that are continuous with, of similar lithotype and characteristics to, and, formerly, parts of the adjacent Superior, Churchill, Nain and, in eastern Labrador, Makkovik provinces to the north. The marginal zone is normally characterized by gradually increased tectonic reworking southward and by greenschist-facies metamorphic overprinting, but although largely co-spatial, the zone should not be confused with the purely tectonic Grenville Front Tectonic Zone (see below). Throughout Labrador, the marginal zone is bounded to the south by the Labrador Orogen (Figure 4), a post-Hudsonian, late Early Proterozoic cycle of sedimentation and orogeny. This orogen lies almost entirely within the Grenville Province, in the northern part of which, it truncates the marginal-zone equivalents of the provinces to the north. In central Labrador, the Labrador Orogen is made up of two main lithological components, the Trans-Labrador batholith (Wardle and staff, 1982) to the north and a southern belt of paragneiss (Figure 5).

The Trans-Labrador batholith comprises a series of spatially associated calc-alkaline to alkali-calcic, predominantly granitoid plutonic rocks associated with minor, more or less coeval, commonly hydrous diorite, gabbro and gabbronorite bodies. Locally, approximately coeval, acid to basic volcanic rocks and clastic sedimentary rocks form remnants of a carapace to the batholith. In places, the batholith is intruded by Middle Proterozoic basic rocks, which probably range in age between ca. 1500 and 1300 Ma; for

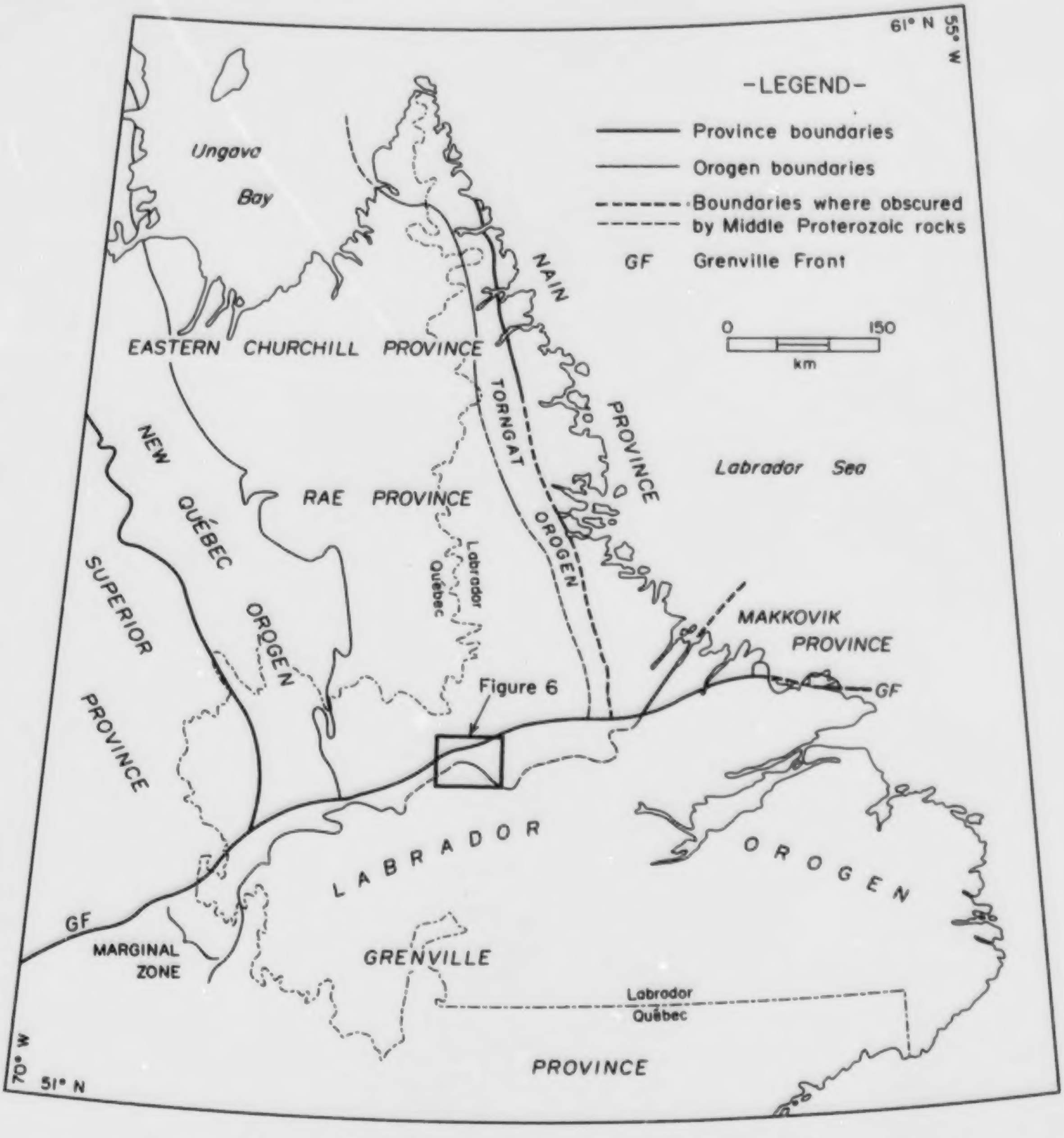

61° N
55° W
-LEGEND-
Province boundaries
Orogen boundaries
Boundaries where obscured by Middle Proterozoic rocks
GF Grenville Front
0 150
km
Ungava Bay
EASTERN CHURCHILL PROVINCE
NAIN PROVINCE
TORNGAT OROGEN
NEW QUÉBEC OROGEN
RAE PROVINCE
Labrador Québec
Labrador Sea
SUPERIOR PROVINCE
MAKKOVIK PROVINCE
Figure 6
GF
LABRADOR OROGEN
GRENVILLE PROVINCE
MARGINAL ZONE
Labrador
Québec
70° W
51° N

Figure 4. *Structural setting of the eastern Ungava Peninsula (Labrador and New Quebec).*

example, the Shabogamo gabbro (Brooks *et al.*, 1981; Zindler *et al.*, 1981) and the Red Wine norite (Brooks, 1984). Products of deformation in the Trans-Labrador batholith range from localized greenschist-facies shear zones in the north to penetrative upper-amphibolite-facies fabrics in the south. South of the batholith, there is a belt of monotonous, aluminous paragneiss characterized by sillimanite, kyanite and mica. Upper amphibolite facies areas of these rocks are commonly overthrust by similar paragneiss at higher (granulite) grade that locally contains sapphirine and/or hypersthene (Thomas and Wood, 1983; Nunn *et al.*, 1984).

The northern margin of the Trans-Labrador batholith is intrusive into, or in tectonic contact with, the rocks in the marginal zone. The southern margin is intrusive into, and infolded and deformed with, the paragneiss; however, gneiss-forming deformation in the paragneiss both predates and postdates emplacement of the batholith. The progressive deformation (increasing southward) across the batholith and

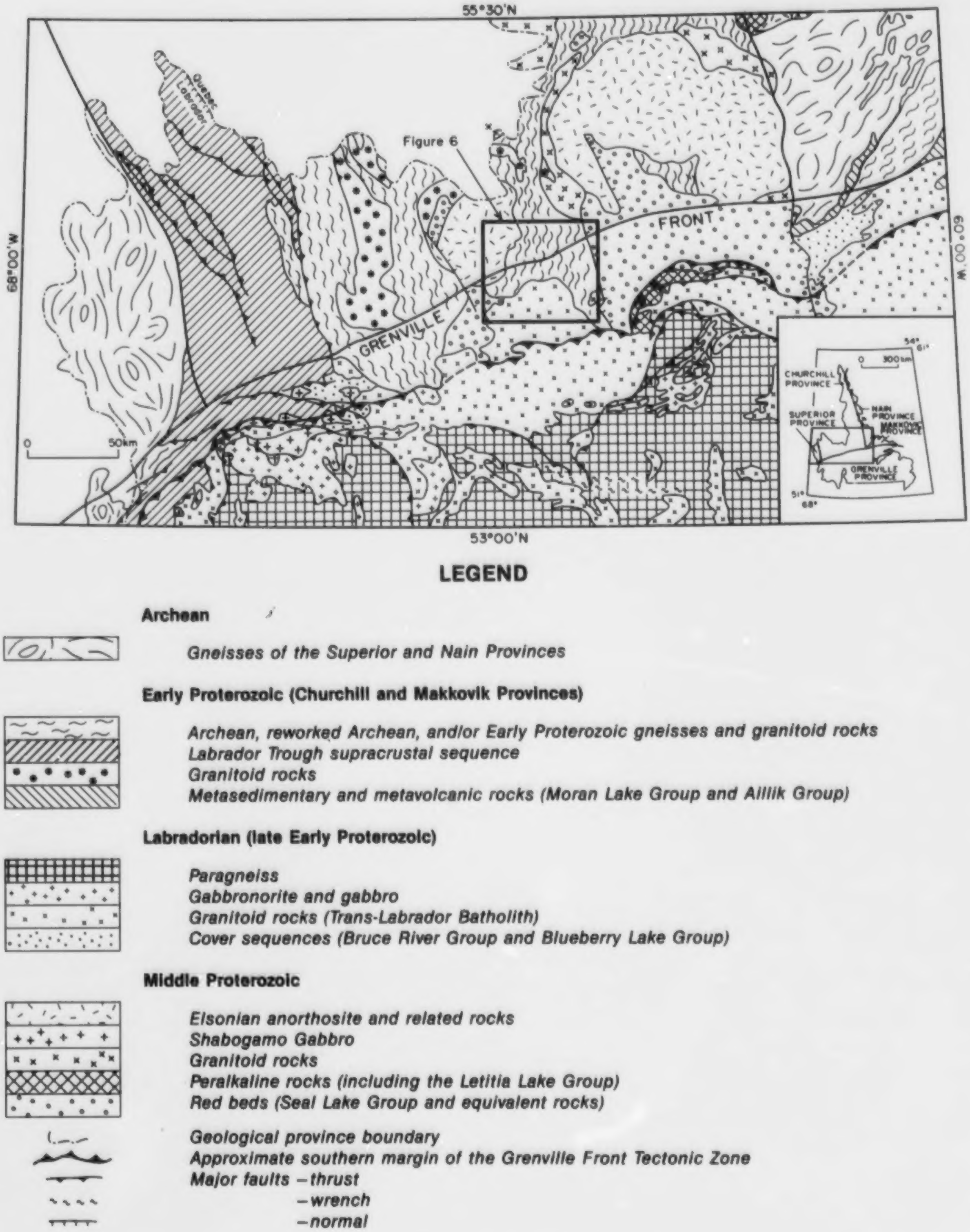

55°30'N
Quebec
Labrador
Figure 6
FRONT
GRENVILLE
68°00'W
60°00'W
0
50km
53°00'N
54°
61°
0
300km
CHURCHILL PROVINCE
SUPERIOR PROVINCE
NAIN PROVINCE
MAKKOVIK PROVINCE
GRENVILLE PROVINCE
51°
68°
LEGEND
Archean
Gneisses of the Superior and Nain Provinces
Early Proterozoic (Churchill and Makkovik Provinces)
Archean, reworked Archean, and/or Early Proterozoic gneisses and granitoid rocks
Labrador Trough supracrustal sequence
Granitoid rocks
Metasedimentary and metavolcanic rocks (Moran Lake Group and Aillik Group)
Labradorian (late Early Proterozoic)
Paragneiss
Gabbronorite and gabbro
Granitoid rocks (Trans-Labrador Batholith)
Cover sequences (Bruce River Group and Blueberry Lake Group)
Middle Proterozoic
Elsonian anorthosite and related rocks
Shabogamo Gabbro
Granitoid rocks
Peralkaline rocks (including the Letitia Lake Group)
Red beds (Seal Lake Group and equivalent rocks)
Geological province boundary
Approximate southern margin of the Grenville Front Tectonic Zone
Major faults – thrust
– wrench
– normal

Figure 5. *The geology of central Labrador.*

coeval tectonism in the paragneiss are Grenvillian, but the earlier high-grade deformation and metamorphism in the paragneiss relate to the Labradorian Orogeny at ca. 1710 to 1620 Ma (Nunn *et al.*, 1985). No equivalents of the Labradorian-grade metamorphism or of the paragneiss compositions are known from north of the Trans-Labrador batholith in Labrador.

The trend of the three-fold division of the eastern Churchill Province, and of the overall tectonic trends of the rock types and fabrics within these divisions, is north–south, whereas that of similar elements in the Grenville Province is broadly east–west. The boundary between the two provinces, the Grenville Front, crosses the northern third of the study area with a roughly east-northeast orientation, and is defined here as the approximate northern limit of Grenvillian deformation. Immediately south of the front is the Grenville Front Tectonic Zone (GFTZ, Figure 5; Wynne-Edwards, 1972), in this region a 40- to 55-km-wide zone of non-penetrative Grenville deformation in which Grenvillian tectonism and metamorphism increase southward. Typically, the GFTZ is manifested by folds and spaced cleavage in cover rocks, by faults and anastomosing shear zones in basement and plutonic rocks, and by greenschist- or subgreenschist-facies metamorphism. The southern boundary of the tectonic zone occurs where Grenvillian deformation becomes predominantly penetrative and is commonly the locus of major thrust faults. However, due to the variation in strain of different rock types in response to the same stress regimes (e.g., cover versus basement), this boundary may be highly irregular.

Main Map Units

A simplified version of the bedrock geology of the map area is shown in Figure 6a. The pre-Pleistocene rock units in the map area fall into three groups, defined, for the most part, chronologically (Figure 6b). These consist of Archean and possible Early Proterozoic (pre-Labradorian) rocks, late Early Proterozoic (Labradorian) rocks and Middle Proterozoic (post-Labradorian) rocks.

Archean and Possible Early Proterozoic

Archean and possible Early Proterozoic rocks occur in the north, east and west-centre of the map area and consist of supracrustal rocks, granitoid orthogneiss and plutonic rocks. In the northeast and east of this area, a supracrustal succession and its metamorphic derivatives (Unit 1) comprises mafic metavolcanic rocks, diatexite, sillimanite paragneiss, gabbroic sills, thinly bedded clastic rocks and minor quartzite. The supracrustal succession is intruded by a suite of partly syntectonic tonalite and granodiorite (now mostly orthogneiss) and lesser foliated granite (Sail Lake intrusive suite, Unit 2). The mafic volcanic rocks dominate the supracrustal succession and are derived from pillow lavas and related rocks; the diatexite is probably derived from a semipelitic protolith. The supracrustal rocks occur as layers, lenses and patches that are enclosed in, and infolded into, the orthogneiss suite–they are mostly strongly foliated and commonly migmatitic. The orthogneiss protoliths intruded the supracrustal bodies, and locally formed agmatite at their margins, and are dominated by tonalitic compositions. The orthogneiss is pervasively migmatized, and it and the younger granitoid rocks are also strongly foliated. Both the supracrustal rocks (Unit 1) and the Sail Lake intrusive suite (Unit 2) are intruded by a massive to strongly foliated gabbro–diorite–granite plutonic suite (Unit 3). All three units are characterized by the common occurrence of, generally steeply pitching, linear fabric elements. The tonalite was emplaced in the Late Archean (2690 to 2660 Ma, Figure 7; Nunn *et al.*, 1990) and was probably migmatized soon afterward (*ibid.*). The association of supracrustal rocks intruded by Late Archean tonalite and subsequently deformed in a Late Archean orogeny, defines the Orma Domain (Wardle *et al.*, 1990) that crops out in the east of the map area. The gabbro–diorite–granite plutonic suite is undated but minor migmatization and similar fabric orientations to those of the orthogneiss suggest a late syntectonic emplacement during the Archean Orogeny, although younger ages cannot be completely discounted.

A major supracrustal sequence, the Petscapiskau Group (Emslie, 1970), crops out west of the centre of the map area. It consists of pelite, mafic volcanic rocks, quartzite, rhyolite-porphyry conglomerate, metagreywacke, interbedded pelite and psammite, psammite and minor metagabbro (Unit 5). Clastic rocks predominate: locally, mafic volcanic rocks are also abundant and, as with Unit 1, are derived from pillow lavas and related rocks (e.g., tuff, hyaloclastite). The unit contains strong bedding-parallel planar fabrics; it is not migmatitic except in the inner part of the contact aureole enclosing an anorthositic intrusion (Unit 10, see below). The adjacent orthogneiss is typical of Unit 2 farther east.

The supracrustal rocks in the east of the map area (Unit 1) show evidence of intrusion by protoliths of the orthogneiss (Sail Lake intrusive suite, Unit 2), however, relationships in the west between the Petscapiskau Group (Unit 5) and the orthogneiss suite are less certain. The relatively low regional metamorphic grade of some of the pelitic rocks may indicate that some or much of the Petscapiskau Group is a cover sequence to the orthogneiss, however, a locality containing gneissic tonalite dykes in pelite suggests a correlation of the Petscapiskau Group with Unit 1. Thus, the westward extent of the Orma Domain in the map area is, at present, uncertain, and the age of the Petscapiskau Group is Archean or possibly Early Proterozoic.

Archean and possible Lower Proterozoic rocks form much of the marginal zone of the Grenville Province within

Figure 6. *(a) General geology and (b) the main rock associations in the map area.*

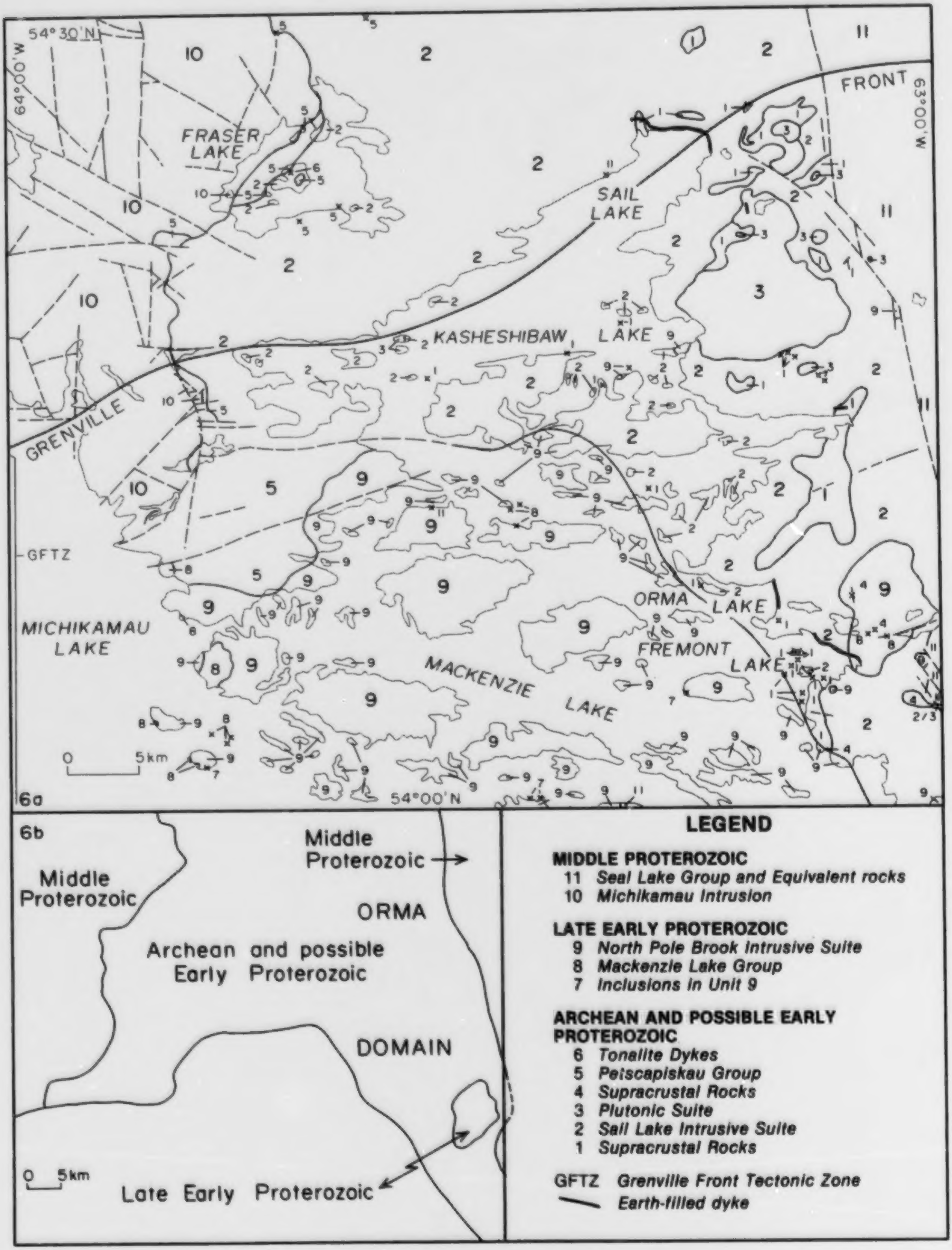

54°30'N
64°00'W
63°00'W
54°00'N
FRASER LAKE
SAIL LAKE
KASHESHIBAW LAKE
GRENVILLE FRONT
GFTZ
MICHIKAMAU LAKE
MACKENZIE LAKE
ORMA LAKE
FREMONT LAKE
0 5km
6a
6b
Middle Proterozoic
Middle Proterozoic
ORMA DOMAIN
Archean and possible Early Proterozoic
Late Early Proterozoic
0 5km
LEGEND
MIDDLE PROTEROZOIC
11 Seal Lake Group and Equivalent rocks
10 Michikamau Intrusion
LATE EARLY PROTEROZOIC
9 North Pole Brook Intrusive Suite
8 Mackenzie Lake Group
7 Inclusions in Unit 9
ARCHEAN AND POSSIBLE EARLY PROTEROZOIC
6 Tonalite Dykes
5 Petscapiskau Group
4 Supracrustal Rocks
3 Plutonic Suite
2 Sail Lake Intrusive Suite
1 Supracrustal Rocks
GFTZ Grenville Front Tectonic Zone
Earth-filled dyke

Figure 6

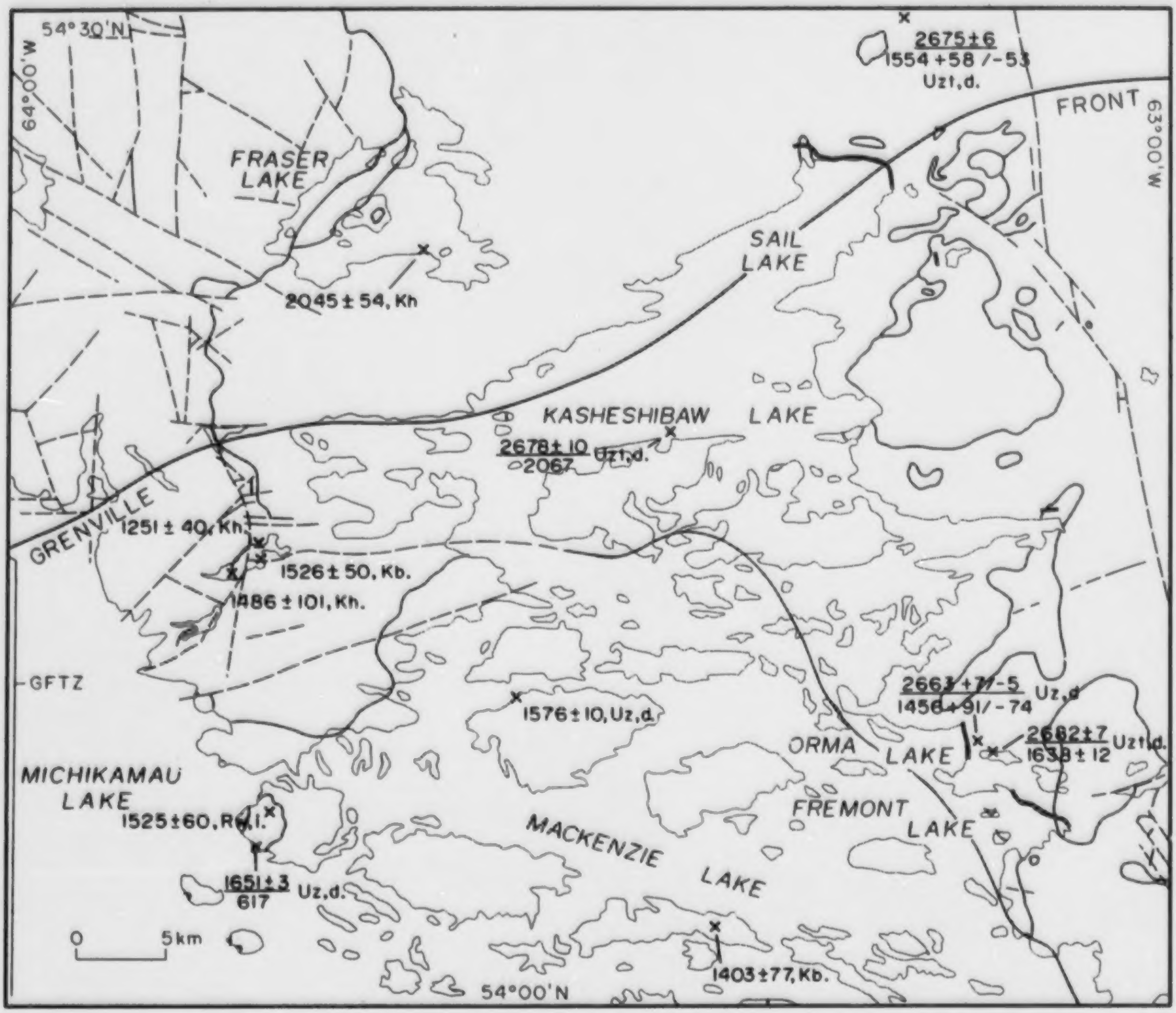

54°30'N
64°00'W
63°00'W
2675±6
1554 +58 /-53
Uzt,d.
FRONT
FRASER LAKE
SAIL LAKE
2045 ± 54, Kh
KASHESHIBAW LAKE
2678± 10
2067
Uzt,d.
GRENVILLE
1251 ± 40, Kh.
1526 ± 50, Kb.
1486 ± 101, Kh.
GFTZ
1576 ± 10, Uz,d.
2663 +7/-5
1456 +91/-74
Uz,d
2682±7
1638 ± 12
Uzt,d.
ORMA LAKE
FREMONT LAKE
MICHIKAMAU LAKE
1525±60, Rb,I.
MACKENZIE LAKE
1651±3
617
Uz,d.
0
5km
1403±77, Kb.
54°00'N

Figure 7. *Radiometric data from the northeastern Smallwood Reservoir map area; abbreviations as in Map 93-19.*

the map area. They also extend northward across the Grenville Front into the southernmost part of the Rae Province. The possible extent of the Orma Domain association (or of the Archean and possible Early Proterozoic assemblage generally) in this direction is not known; however, reconnaissance mapping (Emslie, 1964b) north of the map area and preliminary results of more detailed work even farther north in Quebec (John van der Leeden and Rejean Girard, personal communications, 1990) indicate that these rocks may be extensive in the southern half of the Rae Province in the Labrador–Ungava peninsula.

In the map area, the southern boundary of the marginal zone is an intrusive or tectonic contact with the Trans-Labrador batholith of the Labrador Orogen; several satellite plutons of the batholith occur within the marginal zone. In addition, the Archean and possible Early Proterozoic assemblage is intruded by an anorthositic intrusion in the west and is in fault contact with a younger cover sequence to the east. These features are typical of, respectively, the Rae Province and the marginal zone on a regional scale in Labrador.

Late Early Proterozoic

Late Early Proterozoic rocks (Figure 6b) occur in the south, south-central and southwest parts of the map area. They consist of granitoid plutonic rocks of the North Pole Brook Intrusive Suite (Unit 9) and patches of volcanic and continental clastic rocks of the Mackenzie Lake group (Unit 8). The North Pole Brook Intrusive Suite is dominated by quartz monzonite and quartz syenite that are characterized by potassium-feldspar-megacrystic textures; quartz monzodiorite, granite and hydrous gabbro also occur. The plutonic rocks are massive to moderately foliated. The Mackenzie Lake group occurs as inclusions and roof pendants in the North Pole Brook Intrusive Suite and is intruded by dykes of this granitoid suite. The volcanic rocks in the Mackenzie Lake group consist of andesite, quartz andesite and dacite and the clastic rocks in the group are parallel- to crossbedded (fluviatile?) arenites: the unit is massive and only locally exhibits a tectonic foliation. The granitoid suite was emplaced in, or at the end of, the late Early Proterozoic (1654 to 1646 Ma, Figure 8, and ca. 1576 Ma, Figure 7; Brooks, 1983; Nunn *et al.*, 1985); a similar age of 1651 ± 3 Ma for a hypabyssal andesitic rock (Krogh, 1985) indicates that the Mackenzie Lake group is a coeval carapace into which the granitoid rocks intruded.

The late Early Proterozoic rocks belong to the Labrador Orogen and they represent the northern margin of the regionally extensive Trans-Labrador batholith and its coeval cover (Figure 5). The North Pole Brook Intrusive Suite is the major phase of the batholith east and southeast of the map area (Thomas and Hibbs, 1980; Thomas, 1981, 1993), and also immediately to the south (Nunn, 1982). However, quartz monzodiorite and late stocks of granite and microgranite are much more common parts of the suite in the latter area (Nunn, 1981) in contrast to the present one, and even farther south, equigranular biotite granite and K-feldspar-megacrystic monzonite are major phases in the batholith (Wardle and Britton, 1981; Wardle, 1985). Coeval cover rocks occur 180 km to the east and are termed the Bruce River Group (Figure 5; Ryan, 1981; Schärer *et al.*, 1988).

The northern boundary of the Labrador Orogen is a tectonic or intrusive contact with rocks in the marginal zone of the Grenville Province. Locally, intruded rocks are thermally metamorphosed (e.g., the Petscapiskau and Mackenzie Lake groups) and satellite plutons of the batholith occur within the marginal zone north of the boundary.

Middle Proterozoic

Middle Proterozoic rocks (Figure 6b) crop out in the west and northwest, the east and northeast, and also occur as small, widely scattered bodies throughout the remainder of the map area. The western area is underlain by a layered basic intrusion of anorthositic affinity (Unit 10) termed the Michikamau Intrusion (Emslie, 1964a, 1970) which was emplaced at ca. 1460 Ma (Figure 8; Krogh and Davis, 1973). Its main lithotypes are leucotroctolite and anorthosite. Troctolite, olivine gabbro and gabbro are minor components of the main layered series of rocks, but are major members of a border group. Spatially related iron-rich granitoid rocks occur with the intrusion outside the map area. The intrusion is faulted but otherwise undeformed; it is surrounded by a contact aureole several kilometres wide.

The eastern area is underlain by continental red beds of the Seal Lake Group (subunit 11a; Brummer and Mann, 1961). Red arenite and fine-grained conglomerate are the principal lithotypes in the map area, and in the southern part of the outcrop area, grey arenite is interlayered with basalt and gabbro sills. The red beds are folded; the grey arenite and intercalated mafic volcanic rocks are folded and cleaved. Small patches of red beds, very immature breccia and a distinctive stromatolite-bearing float are thought to be equivalents of the Seal Lake Group (subunit 11b). Dating of mafic volcanic layers and sills in the red-bed sequence (Baragar, 1978, 1981), and of a stratigraphically underlying felsic porphyry (Fryer, 1983) east of the map area, indicates an age of less than 1325 Ma for the continental clastic succession (Figure 8).

The Michikamau Intrusion is in intrusive contact, and the Seal Lake Group is in fault contact, with the Archean and possible Lower Proterozoic rocks in the Rae Province and in the marginal zone of the Grenville Province within the map area. The former is a relationship of regional extent in Labrador. The Michikamau Intrusion is one of a number of anorthositic and granitoid plutons that intrude the Rae Province, the Torngat Orogen and the Nain Province, and that are assigned to a period of anorogenic magmatism between ca. 1500 and 1300 Ma called the Elsonian Orogen by Emslie (1978a).

The red beds were deposited near the end of the same period and they are similarly assigned to this Middle Proterozoic period of anorogenic activity and crustal extension (Emslie, 1978b; Hill and Thomas, 1983). Within, north and east of the map area, the red beds are unconformable on orthogneiss, granitoid rocks and anorthositic rocks of the Rae Province (and its continuation in the marginal zone of the Grenville Province). South of the map area, the red beds unconformably overlie, or are overthrust by, granitoid rocks of the Trans-Labrador batholith (Nunn, 1982). Both of these relationships are also of regional extent in central Labrador (Figure 8).

Within the Rae Province, the red beds and the various anorthositic complexes are undeformed. Within the Grenville Front Tectonic Zone, the red beds are folded and locally cleaved, and the anorthositic rocks are faulted. South of the zone, the red beds are penetratively deformed.

Other Units

Some minor rock units are also present. Migmatitic, arkosic metasedimentary rocks of uncertain affinity (Unit 4) occur in the southeastern part of the Archean and possible Early Proterozoic area. In the northwest of the same area, tonalite gneiss dykes (Unit 6) intrude the Petscapiskau Group. Various rafts of older granitoid, metasedimentary(?) and amphibolitic rocks of uncertain association (Unit 7) are present within the North Pole Brook Intrusive Suite. Small diabase dykes (subunit 12a) are scattered throughout the map area and a plagioclase-megacrystic diabase dyke (subunit 12b) occurs in the southwest of the map area.

Pleistocene deposits (Unit 13) are distributed throughout the map area as a till cover and as areas of glaciofluvial sediment, in part, associated with some large esker systems.

Structural and Metamorphic Variation

Archean

Archean structures and metamorphism occur in the Archean supracrustal rocks (Unit 1), the Sail Lake intrusive

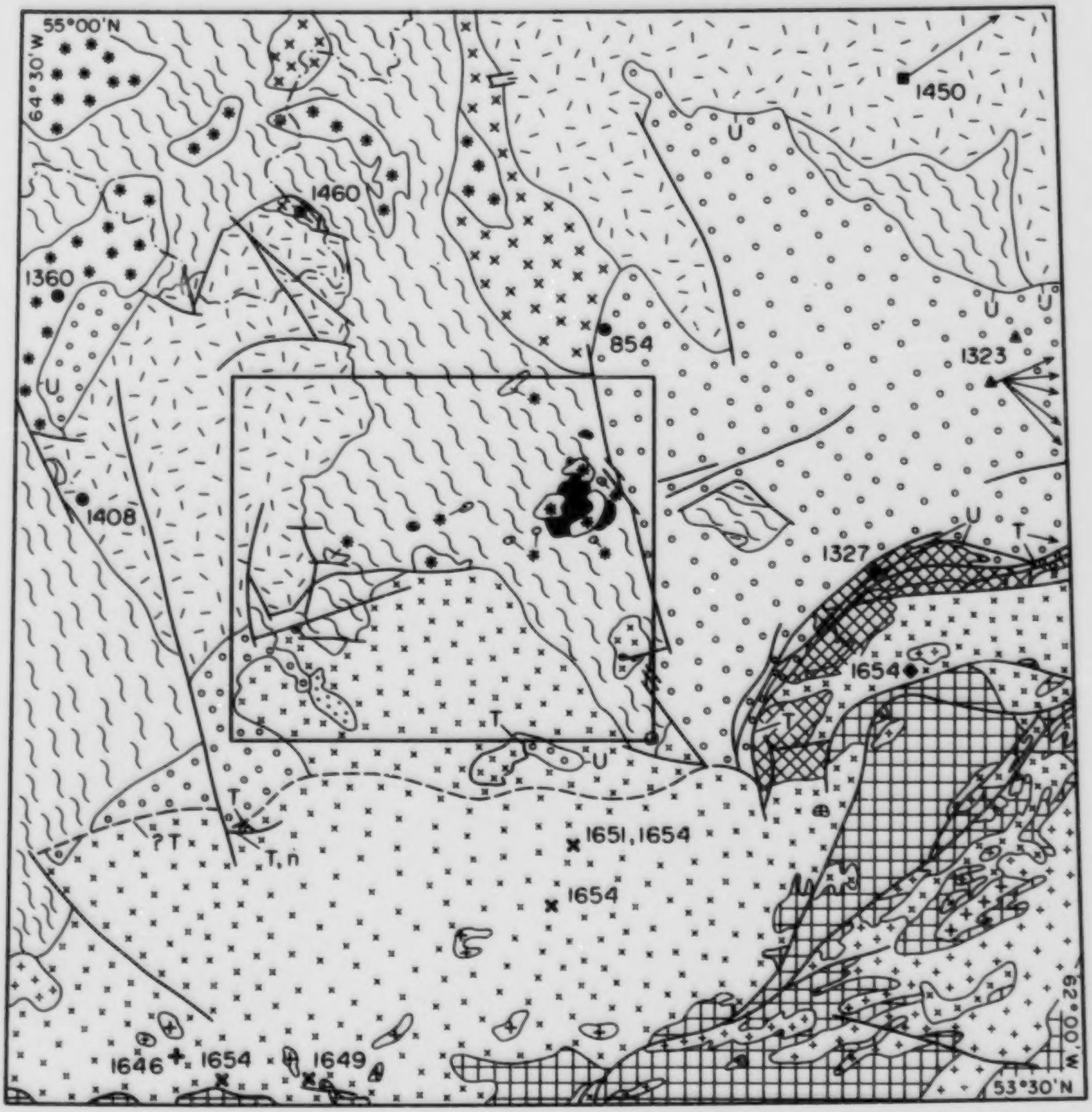


Figure 8. *Regional relationships and radiometric data from west-central Labrador that are referred to in the text but that occur outside of the map area (inset = map area (Figure 6)).*

suite (Unit 2) and, possibly, the gabbro–diorite–granite suite (Unit 3). The main Archean structures consist of tight to isoclinal folding, largely penetrative triaxial or linear fabric development, and broadly coeval migmatization. Migmatites are developed throughout the Sail Lake intrusive suite, but migmatitic supracrustal rocks are more prevalent in the north. This, together with the more widespread presence of diatexite and mineral assemblages that include sillimanite or hypersthene, red-brown biotite and spinel, indicates that the metamorphic culmination during the main Archean orogenesis was in the northern part of the map area.

The tectonic fabrics include variably developed planar features, but are almost everywhere characterized by strong linear elements. Lineations commonly pitch moderately to steeply on the foliation planes in the eastern part of the map area, but in the centre of Kasheshibaw Lake and farther west, they are near horizontal and are associated with major northerly trending mylonite zones. Whether the mylonite zones are an intensification of the main Archean fabric or a younger reworking is not known. Strong linear-fabric elements in, but only minor migmatization of, the gabbro–diorite–granite suite (Unit 3) indicate that this suite

LEGEND (Figure 8)

LOWER PROTEROZOIC AND/OR ARCHEAN

Rae Province (and Marginal Zone)

- ⌇ *Orthogneiss, paragneiss and metasediment including variably reworked Archean rocks and the Petscapiskau Group*
- ■ *Gabbroid rocks*
- ● *Granitoid rocks*

Labradorian

- ⊞ *Paragneiss*
- + *Gabbronorite and related rocks*
- × *Granitoid rocks–Trans-Labrador Batholith*
- ⁘ *Coeval cover–Mackenzie Lake Group*

MIDDLE PROTEROZOIC

Elsonian

- ⌇ *Anorthosite and related rocks*
- × *Granitoid rocks*

- + *Shabogamo Gabbro and Red Wine norite*
- ▩ *Peralkaline rocks–Letitia Lake Group and equivalent plutonic rocks*
- • *Red beds–Seal Lake Group and equivalent rocks*

Regional relationships

T	*Thrust*
?T	*Inferred thrust*
U	*Unconformity*
n	*Overturned unconformity*
— — —	*Faults (inferred)*
———	*Geological contacts*
—·—	*Labrador–Quebec boundary*

Radiometric data in Ma

▲	*Baragar, 1978*
■	*Krogh and Davis, 1973*
◆	*Fryer, 1983*
●	*Wanless* et al., *1965, 1967 (854 Ma)*
×	*Krogh, 1983, 1985 (1649 Ma)*
✚	*Brooks, 1983*

was emplaced synkinematically or late during the Archean orogenesis.

The main fabric development was long lived, as demonstrated by a syntectonic emplacement sequence developed in subunit 2a and by syntectonic relationships in the granite dykes of subunit 2g. Locally, at least, the main fabric development occurred under lower or waning PT conditions (commonly in broad zones of less intense ductile shearing), such that epidote or muscovite were stable members of the assemblage (e.g., south and southwest of the aforementioned culmination).

The main structures were followed by tight to moderate asymmetric folds and shear-zone development, accompanied by more localized migmatization and fabric development, and, subsequently, moderate to open folding. The folding resulted in interference patterns at map scale, producing asymmetric, circular or oval perturbations of varying orientation in the generally northerly oriented structural grain.

Archean or Early Proterozoic

In the units known to be Archean (Unit 1 supracrustal rocks and the orthogneiss suite of Unit 2), one migmatization event has been assumed. The assumption is made because there is no record of a Hudsonian isotopic signature in the dated samples of the Sail Lake intrusive suite tonalite gneiss (Nunn *et al.*, 1990). Potentially younger (Hudsonian) migmatization could not be separated in the field but may be present.

The emplacement and subsequent migmatization of the gabbro–diorite–granite suite (Unit 3) may be Early Proterozoic rather than Archean, but for the reasons given above (see previous section), the Archean is preferred for both events.

Unit 4 is confined to the southeastern portions of the map area and mostly comprises migmatized red arenite. If the reddening is primary, the migmatization is likely to be Hudsonian. (The Archean atmospheric oxygen content was too low for red bed formation.) However, if the reddening is related to recrystallization of feldspar (Tomasz Dec, personal communication, November, 1991) Unit 4 might contain Archean neosomes.

The Petscapiskau Group (Unit 5) occurs mainly in the southwestern part of the Archean and possible Early Proterozoic area and may also correlate with Unit 1.

Structures in the group consist of a quartz-segregation fabric, tight to isoclinal folding of bedding and quartz segregations and axial-planar development of a major bedding-plane-parallel foliation; these structures are somewhat similar to those in the known Archean rocks (Units 1 and 2). However, strongly linear elements in the foliation plane are rare in the Petscapiskau Group. Evidence in favour of Archean structures in the Petscapiskau Group consists of the gneissic tonalite dykes that intrude the group on Rusty Island in Fraser Lake, and the concordance of structures between those in the Petscapiskau Group and those in the adjacent Sail Lake intrusive suite (Unit 2). The most compelling evidence against an Archean correlation, and in favour of Hudsonian structures for the group, comes from the area between Michikamau and Vollant lakes. There, equivalent intrusive relationships are absent, and, away from the thermal aureole around the Michikamau Intrusion, the regional metamorphic grade in the Petscapiskau Group is, at best, upper greenschist facies (see Appendix 2—Regional Assemblages).

Labradorian

The North Pole Brook Intrusive Suite (Unit 9) was emplaced at the end of the Early Proterozoic. The granitoid rocks had no known effect on the basement (supracrustal rocks—Unit 1, Sail Lake intrusive suite—Unit 2) but caused contact metamorphism in the supracrustal cover sequences of the Petscapiskau Group (Unit 5) and Mackenzie Lake group (Unit 8). Hornblende-hornfels grade thermal metamorphism occurred in pendants of the Mackenzie Lake group in both the southeast and the southwest of the map area and adjacent to the presumed contact with the Petscapiskau Group. Within 500 m of the latter contact, the thermal aureole is at chloritoid grade.

Known Labradorian structures are confined to late Lower Proterozoic rocks. In the Mackenzie Lake group in the southwest of the map area, a north to north-northwesterly trending, subvertical to moderately west-dipping greenschist-facies foliation and fracture fabric occur mainly in the more dacitic rocks (subdivision $8a^4$). In the underlying batholith (North Pole Brook Intrusive Suite), a moderately west- to steeply east-dipping, north to north-northeasterly trending, rather indistinct foliation is sporadically developed. The fabric is generally of consistent orientation but locally is reorientated into more northeasterly trending directions or folded by younger (Grenvillian) structures. The fabric either preserves an igneous mineralogy or developed in the greenschist facies. Its commonly protoclastic character and the fact that it does not affect subdivision $11b^1$ shales immediately south of the map area (Nunn, 1982) are the main reasons for an approximately synplutonic designation.

Elsonian

The Michikamau Intrusion (Unit 10) was emplaced at about 1460 Ma and is an Elsonian intrusion (ca. 1500 to 1300 Ma; Emslie, 1978a). It is surrounded by a well-developed thermal aureole that ranges from pyroxene-hornfels facies, adjacent to the intrusion, to albite—epidote-hornfels facies. The aureole may exceed 5 km in width in the most susceptible rock types (pelite).

The Michikamau Intrusion is disrupted by faulting. Some faulting also affects the country rocks (and is probably Grenvillian or younger), but much appears confined to the intrusion and is assumed to be Elsonian (along with emplacement of the intrusion).

Grenvillian

Grenvillian deformation occurs in all the rock groups. The Grenville Front crosses the northern half of the map area with an approximately east-northeasterly trend. North of the front, there is no known Grenvillian deformation; south of it, Grenvillian deformation increases in intensity southward across the remainder of the area. Near the Grenville Front, the structures consist of gentle undulations in the layered Seal Lake Group (subunit 11a) and faults and minor shear zones in the more massive basement rocks (Units 1 to 10). Farther south in the basement, shear zones are wider, exhibit incipient greenschist-facies minerals, and locally reorient earlier structures; quartz, chlorite, epidote and carbonate are associated with brittle structures. In the Seal Lake Group, the folding becomes increasingly tight southward; locally, these folds are north-verging and may possess an overturned limb. Quartz veining commonly is associated with the folding, and in its southernmost outcrops, the subunit includes strong greenschist-facies foliation or alteration. The folding in subunit 11a occurs north of the axis of the Seal Lake Synclinorium (Fahrig, 1957), which is well developed in the main Seal Lake Group basin to the east.

Grenvillian structures are not penetrative at map scale anywhere in the map area. Therefore, the whole of the map area south of the Grenville Front lies within the Grenville Front Tectonic Zone. The zone correlates with the autochthon of Rivers and Nunn (1985).

Post-Grenvillian

Locally, bedding in the Seal Lake Group abruptly increases in dip, from subhorizontal through easterly dipping to subvertical, with greater proximity to the fault contact with the rocks to the west. As this feature generally is present only in the north of the subunit outcrop area, and does not occur where the red beds are significantly folded, the folds are assumed to predate the faulting. The boundary faults to the Seal Lake Group outcrop areas that are of north-northwesterly orientation are thus post-Grenville or, at the earliest, late Grenvillian. They are part of a set of structures that regionally define graben or half-graben, and partly control the present outcrop pattern of the Middle Proterozoic red-bed sequences.

Miscellaneous

Caution is required in assigning brittle structures and greenschist-facies dynamic or static alteration to specific events in many units. They could be either the result of late tectonism and retrogression related to the main orogenic episode in the unit, or belong to any of several possible younger events, which have not necessarily been identified in the chronology. An example of a presently unassigned structure is the major, greenschist-facies mylonite that cuts Unit 9 in the river 5 km east of the Orma dyke.

ARCHEAN

Supracrustal Rocks (Unit 1)

Mafic to felsic metavolcanic rocks, amphibolite, volcaniclastic and pelitic to psammitic metasedimentary rocks and paragneiss, metagabbro, and minor quartzite, diatexite, psephite and ultramafic rock.

Definition and Division

The supracrustal rocks comprise a spatial association of mafic metavolcanic rocks and mafic intrusive rocks (both now amphibolites) together with various clastic metasedimentary rocks and paragneiss. No basement is known to the supracrustal sequence. It crops out in three main areas in the eastern part of the map area. From north to south, these are: 1) north and east of Sail Lake (Figure 9), 2) between Duck Bay and Orma Lake, and 3) south of Fremont Lake. To the north and east of Sail Lake, the main outcrop area is centred 6 km east of the lake and underlies a very irregularly shaped area of about 5 by 6 km. The irregularity is due to interlayering with the Sail Lake intrusive suite (Unit 2) and subsequent interference folding, and intrusion by gabbro and granitic rocks (Unit 3). Subsidiary patches consist of a sinuous 0.5 by 4 km layer trending east-northeast from a quarry 2 km southeast of Sail Lake, a 1.5 by 2 km area 8 km east-southeast of Sail Lake, a 1 by 2 km area 12 km east-southeast of Sail Lake, a 1 by 1.5 km area 7 km southeast of Sail Lake, and a 1 by 2 km area 7 km north of Sail Lake. Smaller patches and isolated outcrops occur at the east and west ends of Sail dyke and 1 km north and 3.5 km northeast of the east end of the Sail dyke. Between Duck Bay and Orma Lake, the supracrustal rocks underlie an elongated, amoeboid-shaped, 14 km by 1.5- to 4-km-outcrop area that trends north-northeast; the unit occurs as a 9 km by 1 to 2 km area trending south-southeast from Fremont Lake. In addition, a 0.5 by 2 km semicircular layer is found 4 km northwest of Duck Bay. The unit also occurs as widely scattered, commonly isolated outcrops or patches within the eastern outcrop area of the Sail Lake intrusive suite (Unit 2), and, in unexposed area, may well underlie more extensive areas assigned to Unit 2.

Excluding the irregularities in the north, most occurrences of Unit 1 are slightly to very elongate and oriented in a broadly northerly direction (± 30°). Foliation trends are generally subparallel to the elongation of the occurrences. (Although not necessarily incorrect, the subparallel foliation trends may partly be an artifact of map interpretation.)

The supracrustal rocks are divided into seven subunits on the basis of rock type and texture.

Age

The supracrustal rocks are undated. A minimum age is given by the dated Late Archean Sail Lake intrusive suite tonalitic orthogneiss (Unit 2, 2690 to 2660 Ma, Figure 7) that intrudes it.

Subunit 1a

Predominantly mafic metavolcanic rocks (including pillow lava) and massive or layered amphibolite containing minor intercalations of other supracrustal subunits.

Distribution

Subunit 1a constitutes about 75 percent of the outcrop area of Unit 1 between Orma Lake and Duck Bay; and is also found scattered throughout the elongate area of Unit 1 stretching south-southeast from the islands in Fremont Lake (where it forms about 55 percent of the unit). In both areas, it is intermixed with metagabbro (subunit 1b) and metasedimentary rock (subunit 1d; e.g., Figure 10 and Table 1). Five kilometres east-northeast of the eastern end of the dyke at Sail Lake, massive amphibolite underlies an approximately 1 km² area of abundant outcrop; three kilometres south of this dyke, layered amphibolite occurs in a large quarry. Isolated outcrops occur in the general area north and east of Sail Lake. Outcrop areas of 0.5 to 1 km² occur south-southwest and southeast of Proof Lake, and isolated outcrops occur 12 and 20 km northwest of Orma Lake.

Description

The main rock type is fine to medium grained, relatively homogeneous amphibolite that is black- or dark-green-weathering. It is weakly banded, metamorphic textured, and commonly hornblende porphyroblastic. Plagioclase and hornblende ± pyroxene ± biotite are the main minerals. Titanite, quartz, opaque oxides and traces of sulphide also occur. Secondary epidotization is common.

Heterogeneous amphibolite exhibits similar mineralogy, grain size, colour and texture as the more homogeneous variety, but is mineralogically layered. Layering is accentuated by epidotization and the development of rare rusty zones. The amphibolite ranges from finely layered (millimetre to centimetre scale) to broadly layered (decimetre to metre scale). Fine-scale layering is partly the result of more intense deformation and locally grades into pillow-like structures (see below). Also, it has developed by deformation from clastic layers, in which the clasts were considerably smaller than the normal pillow forms; the clasts are likely to have been small pillows, agglomerate or pillow-lava breccia fragments. In places, fine-scale layering is the result of intercalations of thin, very fine grained, tuffaceous or metasedimentary, mafic and felsic rock.

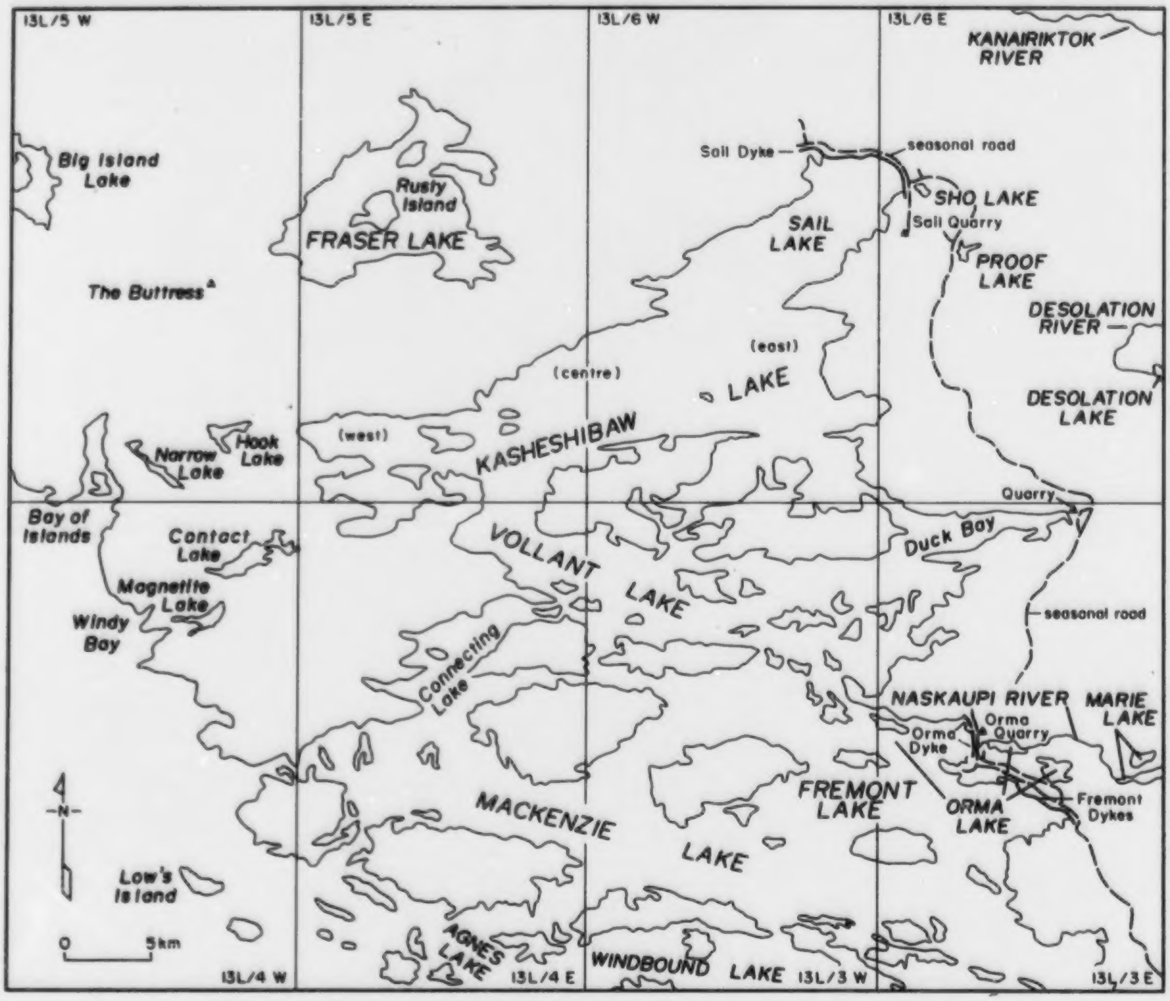

13L/5 W
13L/5 E
13L/6 W
13L/6 E
KANAIRIKTOK RIVER
Big Island Lake
Rusty Island
FRASER LAKE
Sail Dyke
seasonal road
SHO LAKE
Sail Quarry
SAIL LAKE
PROOF LAKE
The Buttress
DESOLATION RIVER
(east)
(centre)
LAKE
DESOLATION LAKE
(west)
KASHESHIBAW
Narrow Lake
Hook Lake
Quarry
Bay of Islands
Contact Lake
VOLLANT LAKE
Duck Bay
Magnetite Lake
Windy Bay
seasonal road
Connecting Lake
NASKAUPI RIVER
MARIE LAKE
Orma Dyke
Orma Quarry
FREMONT LAKE
ORMA LAKE
Fremont Dykes
N
MACKENZIE LAKE
Low's Island
0
5km
13L/4 W
AGNES LAKE
13L/4 E
WINDBOUND LAKE
13L/3 W
13L/3 E

Figure 9. *Approved and informal geographic nomenclature used in this report.*

Figure 10. *Measured section at the west end of the prominent easterly elongated island in the east of Fremont Lake (locality G444a, GR 8963.9420). The local outcrops are designated subunit 1ad on the map and the measured section represents a metasediment-rich portion of the sequence. Vertical scale 1:140.*

The amphibolite (subunit 1a, approximately 30 percent) is dark-green- or black-weathering, dark grey, fine to medium grained, homogeneous or layered and rarely contains a plagioclase spotting (A), and, locally, quartz veining and patches and streaks of epidotization are present (A^e). The metasedimentary rocks (subunit 1d, approximately 50 percent) consist of plagioclase-porphyritic tuffs and minor pelite and thinly layered, siliceous, feldspathic or tremolite-bearing metasedimentary rock (M). Dark-grey, homogeneous, plagioclase–biotite dykes (subunit 2f, first set — see text) are subparallel to the paragneiss layering but in detail transgress the layering in both the amphibolite and the metasedimentary rock (D, approximately 5 percent). Granite (subunit 2g) preferentially occurs in sheets (G, approximately 15 percent) at amphibolite–metasedimentary contacts, or as thin stringers and veins in either lithotype, but also cuts out or cuts across the thicker, less ductile amphibolite layers with sharp, angular relationships.

Stringers (discontinuous veins) of granite (+G) in metasediment and amphibolite, and slivers (screens) of amphibolite (+A) in granite, together with the crosscutting form of the granite sheets in amphibolite, are represented only schematically.

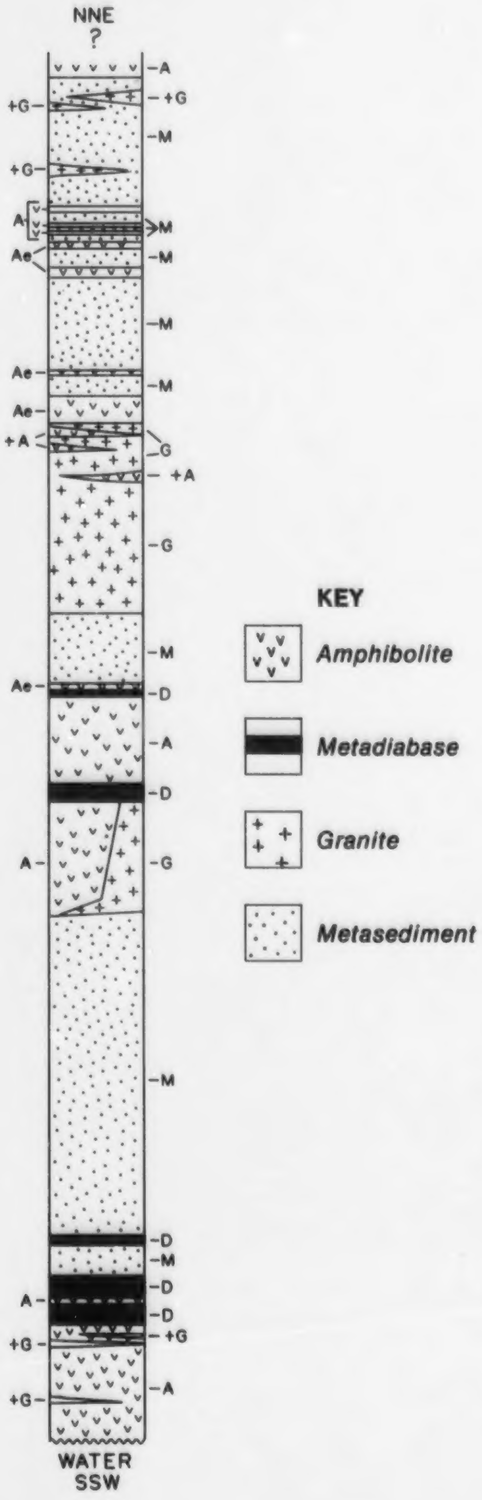


Figure 10. *(caption on opposite page).*

Table 1. List of the lithotypes and their respective thicknesses of the measured section at the west end of the prominent easterly elongated island in the east of Fremont Lake (locality G444a, GR 8963.9420)

Lithotype	Thickness
A	?
M(+G)	2.74 (0-0.22)
A	0.10
M	0.28
A	0.03
M	0.05
A	0.04
M	0.19
A^e	0.10
M	0.44
A^e	0.18
M	2.04
A^e	0.06
M	0.46
A^e	0.56
G(+A)	4.09 (0-0.20)
M	1.52
A^e	0.10
D	0.14
A	1.83
D	0.38
A	2.44-0
G	0-2.33
M	6.70+
D	0.25
M	0.66
D	0.48
A	0.14
D	0.41
A(+G)	2.44 (0-0.08)
Total	29.18

Broad-scale layering locally becomes anastomosing and grades into pillow lavas; several outcrops exhibit pillow younging. Pillows are dark green to grey green and contain black selvages (Plate 1); pillow and interpillow material commonly exhibit patchy epidotization. Weakly deformed pillows range in size from 5 to 50 cm thick and 15 to 120 cm long, and have aspect ratios of 2 to 3:1. Deformation increases pillow length to width ratios, commonly to greater than 6:1, and locally, beyond visual measurement.

Relationships between homogeneous and layered amphibolite are unknown. The weakly banded variety possibly represents indistinct equivalents of the pillow lavas. (When the rocks are wet, the weak banding may not be visible; therefore this rock type may be more extensive.) Large-scale layering, reflecting bedding or flows, is usually defined by intercalations with other subunits, and is normally not seen within amphibolite outcrops. Pillow-lava sequences near the Orma–Sail road, 2 km south of Duck Bay, are up to several hundred metres in thickness.

Pillowed units are most abundant between Duck Bay and Orma Lake and give the best way-up indications in this area. Consistently, they are overturned with their tops to the east. Pillow lavas are also present on the islands in Fremont Lake

Plate 1. *Deformed pillow lava (subunit 1a) having dark outer selvages and/or light inner selvages, light-coloured interpillow material, and the effects of patchy epidotization and saussuritization. Photo and locality NN81-45, NTS 13L/3E, GR 9015.9405. Diameter of lens cap is 5.5 cm.*

and are also suspected to occur in the quarry near Sail Lake. Massive and layered amphibolites of this subunit are otherwise common at all localities.

Most outcrops of this subunit contain either quartz veins and stringers or quartzofeldspathic veins of tonalitic to granitic composition. Larger felsic dykes occur and, rarely, the subunit is net-veined. In the quarry east of Sail Lake, a thin (0.2 to 8 cm) dark-grey and greenish compositional layering is enhanced by 0.1- to 1-cm-thick, *lit-par-lit, in situ* migmatitic sweats exhibiting irregular margins. The sweats consist of a medium-grained plagioclase–quartz–pyroxene–hornblende–biotite rock. Commonly, they increase in thickness and grain size, coalesce, and diverge into branching offshoots that truncate layering. Both sets of veins are commonly pyroxene ± hornblende porphyroblastic, and biotite is preferentially located at hornblende grain boundaries. This migmatitic amphibolite gneiss is best developed toward the south end of the quarry. Passing northward in the west wall of the quarry, the amphibolite gneiss appears to grade into possible flattened pillows.

Hornblendite, amphibolite, diabase (Plate 2) and felsic porphyry dykes cut the subunit, some of which may be feeders to the supracrustal sequence.

*Petrography***

Plagioclase, hornblende and opaque minerals constitute the essential, foliation-forming assemblage in the subunit. In the north, near Sail Lake, clinopyroxene and, less commonly, orthopyroxene are also present, whereas farther south, biotite and epidote form part of the main assemblage. Titanite and apatite are common accessory minerals. Migmatitic veins in the northern parts of the subunit consist of the assemblage plagioclase–quartz–hornblende–biotite–opaque minerals–epidote–titanite–carbonate–zircon. Throughout the subunit, post-foliation alteration has resulted in the crystallization of epidote + chlorite ± biotite ± carbonate, and the saussuritization of plagioclase.

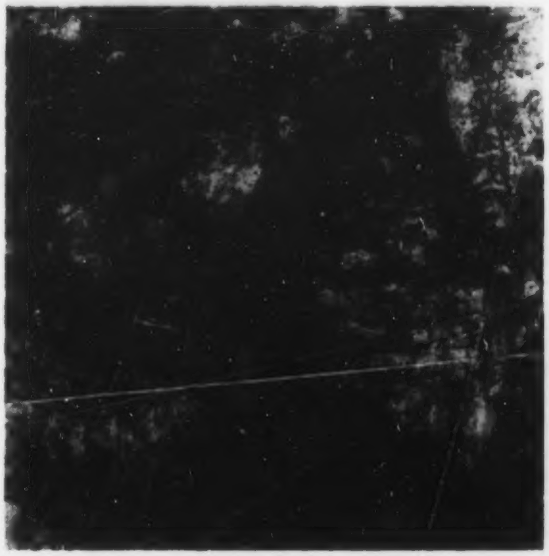


Plate 2. *Mafic dyke (subunit 2f) intruding deformed metabasic pillow lava (subunit 1a). Photo and locality NN81-291, NTS 13L/3E, GR 9300.0715. Diameter of lens cap is 5.5 cm.*

** Some subunit descriptions in this report do not have a *Petrography* section due to the unavailability of rock samples and thin-section descriptions at the time of writing.

Structure and Metamorphism

Subunit 1a contains one main foliation that is generally oriented parallel to the lithological contacts. The foliation is defined by a mineral fabric of plagioclase, hornblende and biotite, and various parallel shape and location fabrics (e.g., deformed clasts, compositional and migmatitic layering) and the fabrics have both planar and linear components. Locally, the main foliation is enhanced by concordant leucocratic segregations (e.g., at the quarry near Sail dyke). First-generation folds of the compositional layering, to which the main foliation might be axial planar, were not seen. Most quartzofeldspathic veins are deformed, either folded, where they are at large angles to the fabric, or necked and boudined, where they are subparallel to the fabric. Mineral fabrics in the veins are commonly less well developed than those in the amphibolite.

Some quartzofeldspathic veins may belong to earlier tectonic events than the main fabric; mostly, they are regarded as broadly syntectonic.

The fabrics and veins generally describe tight to isoclinal folds and associated crenulations. Discordant leucocratic segregations may follow either the axial planes or the limbs of these folds. Rarely, however, is there an associated axial-planar mineral fabric. Irregular shapes and warping indicate minor deformation after the formation of the discordant veining. Hornblende porphyroblasts are randomly oriented in the discordant segregations, but may be isotropically or mimetically distributed, either along the layering or along the foliation, in the amphibolites and concordant migmatite.

Epidotization appears fine grained and amorphous in hand specimen and mostly is later crystallization.

Contact Relationships

Subunit 1a is concordantly intercalated with metagabbro (subunit 1b) and metasedimentary and felsic volcanic rocks (subunit 1d) in southern parts of its exposure area (Figure 10, Plate 3), and is assumed to have a similar relationship with the paragneiss (subunit 1e) farther north. A part of subunit 1a also appears to have a conformable contact, either above or below, with the main part of the pelitic paragneiss (subunit 1f). Locally, subunit 1b metagabbro also has crosscutting intrusive contacts with the compositional layering in subunit 1a (Figure 11). Subunit 1a is intruded by all the members of the Sail Lake intrusive suite (Unit 2) except subunit 2e.

Plate 3. *Banded amphibolite (deformed pillow lava, subunit 1a) in conformable contact with plagioclase-porphyritic tuffaceous rock (right side, subunit 1d). Photo GN80-CS19-23, locality G449a, NTS 13L/3E, GR 9105.9186. Length of hammer is 34 cm.*

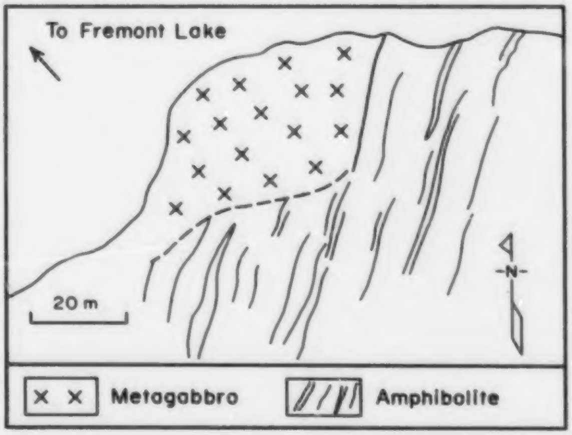


Figure 11. *Example of locally discordant relationships between intergranular-textured metagabbro (subunit 1b) and banded amphibolite (subunit 1a). Drawn from a field sketch. Locality G450a, GR 9130.9122.*

Subunit 1b

Metagabbro having intergranular or plagioclase-cumulate texture.

Distribution

Subunit 1b dominates the supracrustal package east of Sail Lake. It forms a number of 100- to 700-m-wide layers of generally unknown extent and shape, which may reflect interference fold structures. It underlies 35 to 40 percent of the outcrop area of Unit 1 in this region. In the area south of Fremont Lake, metagabbro occurs as layers and bodies up to 500 m across and possibly as much as 3 km long, intermixed with metavolcanic amphibolite (subunit 1a) and metasedimentary and felsic volcanic rocks (subunit 1d); it underlies about 30 percent of Unit 1 in this area. It also occurs in similar but smaller bodies between Duck Bay and Orma Lake, where it forms approximately 10 percent of Unit 1.

Other small outcrop areas are present 7 km west-northwest of Duck Bay, by the road 6 km north-northwest of Duck Bay, and 12 km due north of Duck Bay. Isolated exposures occur beside the road 2 km southwest of Proof Lake, 7 km southeast of Proof Lake, and 5 km west of the north end of Orma dyke.

Description

Subunit Ib comprises varied metagabbroic rocks. Except in the Fremont Lake area, all the outcrops of the subunit consist of various facies of a white-spotted, grey-weathering, plagioclase-cumulate gabbro or leucogabbro (e.g., Plate 4). The cumulus plagioclase is equant to stumpy, generally partially rounded and ranges from several millimetres across up to 10 by 4 cm. The cumulus crystals range from crystal supported (Plate 4) to scattered (less than 20 percent in concentration), and, although they are usually of uniform size, their distribution is inhomogeneous. Rarely, a weak layering occurs.

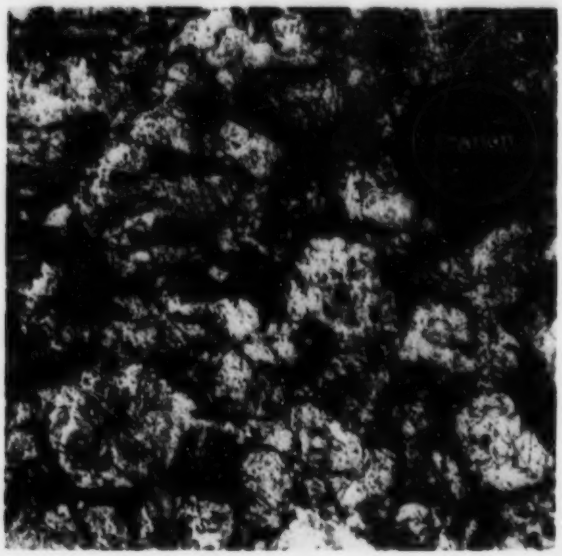


Plate 4. *Saussuritized, primary cumulus plagioclase in hornblendite groundmass of metagabbro (subunit Ib). Photo and locality NN81-277, NTS 13L/3E, GR 9328.0665. Diameter of lens cap is 5.5 cm.*

In the least deformed rocks, the intercumulus material is medium grained and consists of partially chloritized pyroxene. However, most rocks are more thoroughly recrystallized and hornblende is the normal intercumulus ferromagnesian mineral. Intercumulus compositions range from gabbroic to ultramafic giving a bulk rock composition of leucogabbro or gabbro. Gabbroic intercumulus material contains a relict intergranular to subophitic texture; hornblendite intercumulus material is granoblastic or decussate.

Deformation and recrystallization states vary considerably. Relict plagioclase cumulus crystals occur (Plate 4), but even in very weakly deformed rocks, the plagioclase is normally recrystallized to a white, polygonal aggregate. Deformation fabrics are either penetrative or inhomogeneous, and are extreme in some shear zones that range from a centimetre to several metres in width. In the most intensely sheared rocks, the relict plagioclase cumulus crystals are fine-grained, very flattened or stretched aggregates, and the ferromagnesian groundmass consists of wispy, hornblende schlieren. Locally, the rock is a fine-grained amphibolite gneiss.

Several other cumulate rock types occur. The quarry on the side road at the east end of Duck Bay contains a 12-m-thick layer of cumulate metagabbro within massive amphibolite (subunit Ia). The cumulus plagioclase crystals are rectangular, up to several centimetres long, inhomogeneous in both size and distribution, saussuritized (green coloured), and surrounded by a sheared amphibolite groundmass. On the road northwest of Duck Bay, gabbro and leucogabbro are both layered and laminated. Cumulus plagioclase is more lath-like at this locality and seems to have formed glomeroporphyritic aggregates in some places; the intercumulus material is hornblende.

In the Fremont Lake area, and scattered throughout the areas farther north, the metagabbros are predominantly grey, dark-green or black amphibolites that are medium grained and locally contain intergranular to ophitic igneous textures. The igneous textures are relict and are normally seen only at right angles to the lineation (Plate 5). The most common variant is medium-grained, homogeneous or hornblende-porphyroblastic, metamorphic-textured amphibolite. The

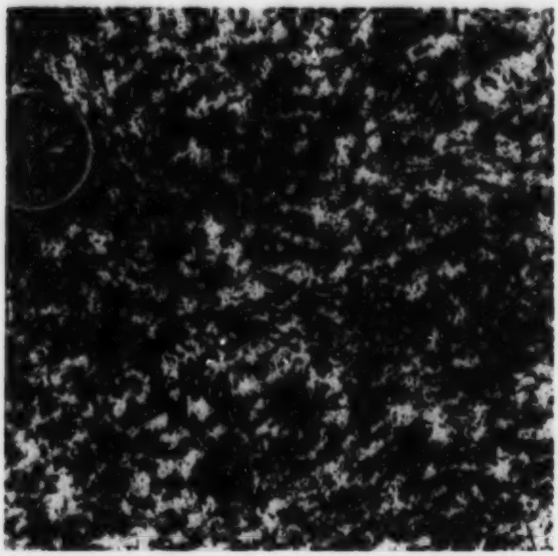


Plate 5. *Deformed metagabbro (subunit Ib) containing poorly preserved, relict igneous texture in areas of low strain and crenulation of the main fabric in areas where the fabric was better developed. Photo GN81-CS24-33, locality G531, NTS 13L/3W, GR 8350.9895. Diameter of coin is 1.85 cm.*

amphibolites are massive and range in composition from leucogabbro to melagabbro. Pegmatitic facies are rare. Although cognate inclusions of slightly different composition occur, agmatitic rocks are usually the result of leucocratic net-veining. In the centre of a net-veined layer, 8 km east of Sail Lake, deformation is relatively minor and the fine-grained rock preserves an original pyroxene and plagioclase porphyritic mineralogy. Toward the edge of the layer, the rock becomes a fine-grained amphibolite gneiss. Grain-size layering in some otherwise homogeneous amphibolites or metagabbros may have been produced in zones of more intense deformation.

The only compositionally layered rocks in the Fremont Lake area occur at the southern end of the linear outcrop area on the shores of Mackenzie Lake. In one place, cyclically alternating layers of medium- to coarse-grained, equant plagioclase and hornblende are 2 to 5 cm thick. Some layers are discontinuous but truncations were not observed: about 10 percent of the layers are modally rhythmic and indicate overturning with tops to the east. Elsewhere, inclusions of metagabbro in quartz diorite and tonalite (Unit 2, Sail Lake intrusive suite) locally exhibit layered concentrations of plagioclase phenocrysts.

Relationships between the cumulate and non-cumulate gabbroic rocks are unknown. They are not in contact and occur near each other only at the southern end of the Fremont Lake area.

Spatially associated with the metagabbros in various parts of the Fremont Lake area are quartz-bearing amphibolites, and quartz diorite to tonalite containing up to 15 percent quartz (M > 30). In places, they are gradational into normal amphibolite whereas elsewhere they are a distinctly separate intrusive phase. (The latter may be early members of the Sail Lake intrusive suite.)

Structure and Metamorphism

The main foliation in subunit 1b metagabbro is subparallel to the elongation of the Unit 1 outcrop areas south of Fremont Lake and between Duck Bay and Orma Lake. North and east of Sail Lake, it follows the general layering trends within Unit 1, but these are of variable orientation due to subsequent interference-folding patterns. This foliation is composed of mostly penetrative mineral and shape fabrics; locally, it intensifies into a gneissosity and concordant shear zones. Linear components are more obvious in the homogeneous metagabbro, and planar elements are more obvious in the cumulate metagabbro, the basic gneisses and the shear zones. The dynamic mineralogy consists of hornblende, plagioclase and biotite, and includes syntectonic porphyroblast growth. Associated leucosomes are usually minor.

No earlier fabrics or metamorphism are known from this subunit.

Locally, the main foliation is preserved in agmatitic blocks. The enclosing leucocratic net veins (excluding those associated with the emplacement of the Sail Lake intrusive suite) generally postdate the fabric in the blocks, but commonly are also deformed. They are probably syn- to postkinematic with respect to the main deformation. Much crystallization is also postkinematic, and static textures and posttectonic hornblende porphyroblasts are common. There is no change in mineral facies during this crystallization.

The main foliation is folded, locally crenulated (Plate 5) and cut by discordant shear zones. The folding is less common than in the well-layered rocks of other subunits and folding and crenulation have no associated new mineral growth. The shear zones involve either rotation or recrystallization, but the latter also contain a typical amphibolite mineralogy.

Felsic, quartz and epidote veins and veinlets crosscut the fabric and are folded during the younger events. Greenschist-facies retrograde phases epidote and chlorite are also present.

Contact Relationships

Subunit 1b occurs in association with mafic metavolcanic rock and amphibolite (subunit 1a), metasedimentary and felsic volcanic rocks (subunit 1d), and paragneiss and diatexite (subunit 1e) and appears to be intruded into them as a series of sills and discordant bodies (e.g., see Figure 11). The subunit is intruded by dykes, and locally net-veins, on an outcrop scale by tonalitic rocks (subunit 2a), orthogneiss (subunit 2c) and granitic rocks (subunit 3c), and on a larger scale it is intercalated with kilometre-scale sheets of the orthogneiss (subunit 2c).

Subunit 1c

Ultramafic intrusive rocks.

Distribution

This subunit occurs in three small outcrop areas: one in the southern part of Kasheshibaw Lake, one by the south end of the Orma dyke, and one on the shore at the eastern end of Mackenzie Lake.

Description

Subunit 1c at Mackenzie Lake consists of several outcrops of brown-weathering, green and brown, coarse-grained, fresh melagabbroic to ultramafic rock. The green and brown colours are due to clinopyroxene or amphibole and hypersthene respectively; black, poikiloblastic hornblende and minor plagioclase make up the remainder of the rock. The outcrops are homogeneous, relatively unfoliated, and cut by diabase and pegmatitic granitoid dykes. In contrast, the other two localities are extensively amphibolitized with few relicts of a peridotite mineralogy present. Both localities contain green-weathering ultramafic rock that grades into hornblende-porphyroblastic green melagabbro or amphibolite and that are net-veined. The hornblende porphyroblasts range up to 2.5 cm across. At the south end of the Orma dyke, a relict layering (Plate 6) is preserved in the ultramafic rocks and the net-veining (Plate 7) is coarse-grained to pegmatitic and commonly has a good peg structure or is grain-size zoned (Plate 7). In the south of Kasheshibaw Lake, the ultramafic rock is homogeneous and the quartzofeldspathic veins are strongly foliated and complexly deformed.

Plate 6. *Layering in amphibolitized ultramafic rock (subunit 1c). Photo GN80-CS17-27, locality G457c, NTS 13L/3E, GR 8924.9675. Diameter of coin is 2.5 cm.*

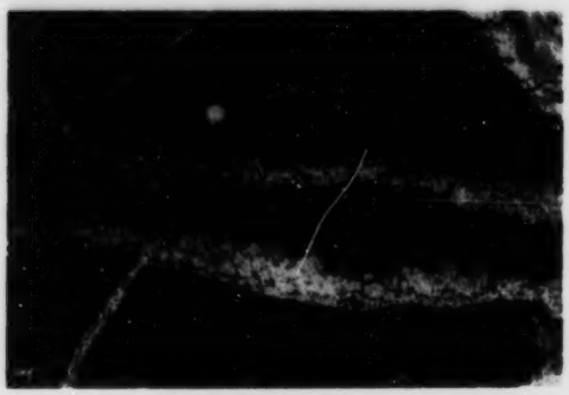


Plate 7. *Compositionally and grain-size-zoned pegmatitic net-veins in mafic amphibolite (meta-melagabbro, subunit 1c). Photo GN80-CS22-6, locality G457c, NTS 13L/3E, GR 8924.9675. Length of clinometer is 10 cm.*

The ultramafic rocks are regarded as intrusive bodies.

Petrography

The layered ultramafic rocks from the south end of the Orma dyke vary from being completely amphibolitized to darker layers (e.g., Plate 6) containing relict orthopyroxene, olivine and plagioclase. The adjacent melagabbro contains about 30 percent relict clinopyroxene and plagioclase enclosed in coalescing hornblende poikiloblasts.

Structure and Metamorphism

The ultramafic and adjacent melagabbroic rocks are cut by shear zones. Net-veining of the bodies (Plate 7) is interpreted as a brittle response to the deformation that induced ductile fabrics in the surrounding gneisses. Subsequent deformation was commonly localized along the veins and granitoid sheets. Due to the relatively brittle nature of the deformation in the ultramafic rocks, it is not easy to correlate their deformation history with that of the orthogneiss host.

Contact Relationships

At the southern end of the Fremont Lake area, the ultramafic rocks occur interspersed among metagabbro of subunit 1b; otherwise they form isolated areas of Unit 1. Granitoid sheets and leucocratic veins cut both the ultramafic rocks and the main phases of the Sail Lake intrusive suite (Unit 2); however, there are no direct contact relationships with the latter.

Subunit 1d

> *Felsic volcanic rocks (tuff and pillow lava) and thinly bedded volcaniclastic and siliceous metasedimentary rocks having minor intercalations of other supracrustal subunits.*

Distribution

The main outcrops of subunit 1d occur between Duck Bay and Orma Lake where they form about 10 percent of the Unit 1 area, including a 5.5 by 0.75 km north-trending zone and several smaller zones of similar trend. In the north of the map area, subunit 1d is exposed in two outcrops at the west end of the Sail dyke, and in a 1 by 0.5 km area 6 km north of the dyke. Numerous thin intercalations in amphibolite (subunit 1a) occur in the south of the map area in the Fremont Lake region (Figure 10 and Table 1).

Description

The diagnostic rock types of this subunit are crystal and crystal-lithic felsic tuffs, thinly bedded siliceous or volcaniclastic sedimentary rocks, felsic pillow lava and polymictic conglomerate. Less common rock types include garnetiferous pelite, tremolite-bearing laminated siltstone, laminated feldspathic siltstone lenses or layers, thin quartzite and monomictic conglomerate. All parts of the subunit are conformably interlayered.

The crystal and crystal-lithic felsic tuffs are cream, grey- or brown-weathering, fine grained, and plane bedded on a centimetre to metre scale. Plagioclase and/or hornblende phenocryst relicts, 1 to 3 mm across, are characteristic. The tuffs are usually strongly foliated; however, normal to the lineation, equant or stumpy crystals suggesting relict porphyritic textures can still be observed. Diffuse lensoid to banded patterns of brown-weathering tuff in an identical-looking grey-weathering matrix may represent cognate clasts in a pyroclastic or air-fall tuff. Thicker, homogeneous, feldspar-rich layers may be flows.

The thinly bedded sedimentary rocks are siliceous, feldspathic and/or tuffaceous, and cream, green or grey weathering. They range from cherty to arenaceous, are bedded on a centimetre scale and commonly contain internal parallel laminae. Locally, graded greywacke layers occur, and the less common rock types, including quartzite (Plate 8) and pelite, are normally found in this association. Rusty layers are also common. Folded quartz segregations and quartzofeldspathic veins are widespread in the thinly bedded units, which are themselves tightly or complexly folded (Plate 8).

Plate 8. *Refolded isocline defined by quartzite layer in metasedimentary sequence (subunit 1d) – foliation is axial planar to the earlier fold generation. Photo and locality NN81-64, NTS 13L/3E, GR 9093.9068. Diameter of lens cap is 5.5 cm.*

Coarser grained and thicker bedded rocks are represented by polymictic and rare monomictic conglomerate. The former contains a variety of clasts up to cobble size, including rhyolitic and quartz-feldspar-porphyritic felsic volcanic rock, siltstone, microgranite, intermediate (± feldspar-phyric) volcanic rock, diorite and mafic rock. The monomictic conglomerate is tuffaceous or volcaniclastic containing andesitic(?) or feldspathic clasts. The clasts are variably deformed depending upon their competence.

The felsic pillow lavas are light-green weathering with dark selvages (Plate 9); they occur only on the islands in Fremont Lake. The pillows are small (up to 20 cm thick and less than a metre long) in contrast to those in subunit 1a.

Petrography

The plagioclase-porphyritic crystal tuffs are composed of plagioclase + hornblende + opaque minerals + epidote + minor quartz, and exhibit varying degrees of chlorite alteration. Fine-scale layering in these rocks is due to variations in hornblende content. All minerals except chlorite crystallized in a dynamic regime during foliation development; zones of stronger deformation contain porphyroclastic feldspar, quartz, epidote and hornblende in an epidote-rich matrix. The porphyritic plagioclase contains subgrains or is recrystallized to an aggregate. Chlorite represents either posttectonic mimetic or random crystallization.

Plate 9. *Deformed felsic pillow lava having dark selvages (subunit 1d). Photo GN81-CP43-8, locality G444a, NTS 13L/3E, GR 8970.9420. Length of hammer is 34 cm.*

The thinly bedded and laminated metasedimentary rocks contain a fine compositional layering in which either quartz, microcline or plagioclase is the main felsic mineral. Although quartz is always present, microcline and plagioclase are locally absent or minor. Hornblende and/or biotite, epidote and titanite are the other common constituents; allanite, zircon, carbonate and apatite are accessory phases in various layers. Hornblende and epidote are commonly porphyroblastic and some hornblende is sieve textured. These and the felsic minerals, together with biotite, titanite and zircon, define the foliation. The carbonate and some epidote may be secondary.

A volcaniclastic arenite from north of Sail Lake contains the assemblage plagioclase–quartz–hornblende–biotite–opaque minerals ± epidote ± tremolite, and chlorite alteration of biotite. Coarser grained layers occur, in which modal biotite varies from negligible to approximately equal to modal hornblende, and finer grained layers are present that lack tremolite and epidote. The tremolite occurs as separate prisms or as overgrowths on hornblende, and these two minerals and biotite define the foliation. Epidote forms ragged overgrowths on hornblende or occurs as euhedral laths overprinting the foliation.

Tremolite is also a component of some laminated siltstone south of Fremont Lake. It was found in the assemblages quartz–tremolite–plagioclase–opaque mineral (a calcareous quartzite), and plagioclase–quartz–tremolite–opaque mineral (a calcareous arkose). The tremolite defines a strong lineation. In the same area, in another of the less common rocks types, pelitic layers contain garnet. The garnet is sieved and ragged and has both euhedral to subhedral, or very anhedral outlines. It forms equant grains (0.5 to 1 mm across) or is weakly elongated (1.5 to 3 mm long), and it overgrows the foliation, which is also slightly flattened around the garnet porphyroblasts. The foliation is defined by a strong biotite alignment, a moderate felsic mineral fabric, and weak garnet and opaque mineral mineral fabrics.

Structure and Metamorphism

The subunit contains a generally strong, bedding-parallel foliation that is more or less north trending throughout. Mineral growth coincided with the foliation development, but recrystallization outlasted the deformation and many of the rocks are annealed.

In the thinly layered parts of the subunit, the layering, the foliation, and the crosscutting quartz or quartzofeldspathic veins are folded to form interference patterns (Plate 8).

Contact Relationships

Subunit 1d is conformably intercalated with the mafic metavolcanic rocks and amphibolite of subunit 1a (Figure 10 and Table 1) and to a lesser degree with metagabbro (subunit 1b) and quartzite (subunit 1g). Interbedded banded amphibolite and mafic breccia (subunit 1a) are commonly more voluminous than the definitive rock types. The intercalations are truncated by emplacement of the tonalitic rocks (subunit 2a) of the Sail Lake intrusive suite in the Fremont Lake area.

Subunit 1e

> ***Pelitic to psammitic paragneiss, and derived diatexite, and minor intercalations of other subunits.***

Distribution

The four areas of subunit 1e occur in the Unit 1 area to the east of Sail Lake, where they form irregular-shaped layers or areas, 200 to 2000 m across, in the gneisses. The largest (about 1.5 by 2 km) occurs 7 km east-northeast of the east end of the Sail dyke, two similar-sized areas (about 0.5 by 1.0 km) are 3 km east and 5.5 km east-southeast of the dyke, and the smallest area (200 by 600 m) is 3.5 km northeast of the dyke.

Description

Subunit 1e comprises two rock types: a white- to light-grey- and rarely pinkish-weathering, feldspar-rich diatexite, and a brown-weathering, pelitic to psammitic paragneiss that occurs as layers and enclaves in the diatexite. Garnet-rich leucosome, containing posttectonic garnet up to 3 cm across (Plate 10), in the pelitic paragneiss locally grades into, or merges with, diatexite. The diatexite is medium to very coarse grained or pegmatitic, and commonly graphic textured. Garnet (up to a centimetre across) is also common in the diatexite and locally has a green phyllosilicate rim. Biotite forms restite patches and schlieren, and sillimanite is a minor constituent. In the northeastern area of subunit 1e, the diatexite forms massive sheets, tens of metres thick. The paragneiss layers and inclusions consist of fine- to medium-grained feldspar + quartz ± biotite ± garnet, and are either homogeneous or gneissic. The gneissosity is either a weakly to well-developed, quartzofeldspathic, migmatitic layering or a quartz-segregation layering. Cordierite occurs in some samples. Garnet is up to a centimetre across.

Plate 10. *Posttectonic garnet porphyroblasts in leucosome to pelitic paragneiss (subunit 1e). Photo GN81-CP37-15, locality G711, NTS 13L/6E, GR 9180.3160. Diameter of coin is 2.5 cm.*

Biotite-restite seams and layers and rusty-weathering zones also occur throughout, and in the area east of the Sail dyke, rare amphibolite and thinly bedded tuff or volcaniclastic sedimentary rocks are interlayered in the subunit. Centimetre- to metre-scale sheets of diatexite occur throughout the well-layered paragneiss and commonly dominate.

Petrography

In the diatexite, the garnet is equant, subhedral to poikiloblastic and rimmed by green, brown-green or red-brown biotite. Garnets in the brown-weathering paragneiss are more strongly poikiloblastic and usually elongate. Diatexite in the centre of the area east-northeast of the Sail dyke contains hypersthene and red-brown biotite, both of which locally exhibit coronas of red-brown biotite intergrown with quartz, and garnet (grown at the expense of both of the ferromagnesian minerals), rare hercynite, myrmekite, and (late) chlorite rims around hypersthene. Graphic textures in the diatexite include perthitic K-feldspar runes in a plagioclase host, as well as the more usual quartz in feldspar.

Structure and Metamorphism

Compositional, segregation and migmatitic layering in the paragneiss is commonly regular and locally folded, but it is rarely complexly contorted. The foliation mostly parallels the layering. Diatexite sheets are concordant to narrowly discordant and continuous for decametres. The foliation appears common to both lithotypes and is defined by plagioclase, quartz, red-brown biotite, hypersthene, sillimanite and garnet. Garnet exhibits both a syntectonic and posttectonic (Plate 10) morphology. Green biotite and chlorite rims to garnet and hypersthene indicate late static retrogression.

Contact Relationships

Subunit 1e is probably interlayered with metagabbro (subunit 1b) within the supracrustal sequence, and at its southern contact, diatexite in the area east of the Sail dyke contains enclaves (boudins?) of plagioclase-cumulate metagabbro (subunit 1b). Subunit 1e is also interlayered and infolded into Sail Lake intrusive suite granitoid orthogneiss, principally subunit 2c, which represents interference deformation patterns of an intrusive relationship between the two.

Subunit 1f

Pelitic paragneiss and minor intercalations of other subunits.

Distribution

Subunit 1f occurs in four places: an approximately 4 by 1 km, north-northeast-trending elongate area 5 km southeast of Sail Lake; a group of three small islands in the easternmost part of Kasheshibaw Lake; two small outcrops 1 km north of the Sail dyke; and an outcrop 6 km north-northwest of Duck Bay.

Description

Subunit 1f is predominantly pelitic paragneiss that is well layered on a centimetre to decimetre scale. The layering consists of concordant compositional alternations of medium- to coarse-grained micaceous material (mica schist may form the whole rock) with fine- to medium-grained feldspathic psammite and thinly bedded quartz psammite or quartzite (Plate 11). An associated amphibolite layer may be part of the supracrustal sequence or a dyke. The micaceous layers contain up to 100 percent biotite and muscovite, with varying proportions of feldspar, quartz and, locally, garnet and sillimanite. Pyrite-bearing rusty layers are common (Plate 11). Sillimanite-rich aggregates form lenses and discontinuous laminae in biotite–sillimanite pelite north of the Sail dyke.

The compositional layering is enhanced by subparallel quartz or quartzofeldspathic veins, which are largely responsible for the gneissic appearance of the subunit. In the outcrop areas at Kasheshibaw Lake, north-northwest of Duck Bay, and the southern end of the area southeast of Sail Lake, only quartz veins are present, whereas elsewhere, quartzofeldspathic and granitoid veins occur in addition to the quartz veins. North of the Sail dyke, the exposures are also intruded by tonalite dykes and sheets.

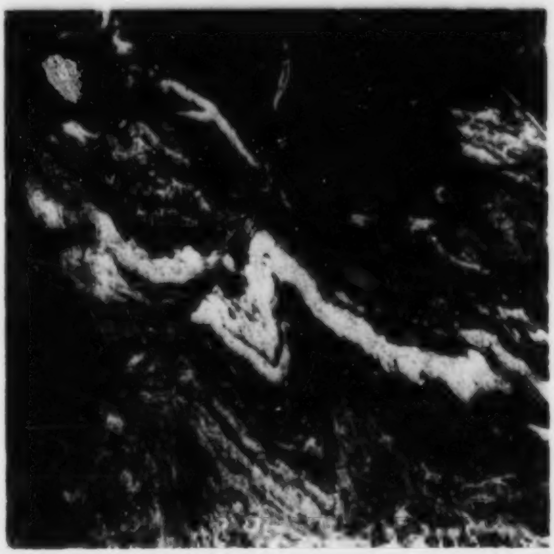


Plate 11. *Isoclinally folded quartzite (white) and rusty-weathering (darkest grey) layers in pelitic paragneiss refolded by asymmetric folds (subunit 1f). Photo GN81-CS33-36, locality G625c, NTS 13L/6W, GR 7872.1715. Length of hammer is 34 cm.*

The micaceous foliation is, locally, axial planar to isoclinal folds of the compositional layering, but, mostly, is parallel to this layering. The layering, veins and foliation are all complexly folded and exhibit contorted patterns resulting from asymmetric refolding of isoclinal folds (e.g., Plate 11). On the islands in Kasheshibaw Lake, the micaceous foliae enclose irregular, elongate (up to 15 by 1 cm) or equant (up to 6 by 5 cm) clots of a green mineral (?pinnite, see petrography below). Elsewhere, garnet is flattened in the foliation and locally chlorite plates are present.

The pelitic paragneiss is mostly dark coloured containing light-weathering veins, brown-weathering psammitic to semipelitic layers, and rusty zones. In Kasheshibaw Lake, a greater proportion of muscovite, chlorite and the large, green, mineral clots impart a greenish colouration to the outcrop.

Petrography

In the mica schist from Kasheshibaw Lake, the micaceous layers are composed of chloritized biotite that forms sheaths, strain shadows and laminae around the green mineral clots. The clots comprise felted and coarse plates of isotropic-textured muscovite pseudomorphing an unidentified mineral (low relief, grey birefringence; ?cordierite) that contains fibrolite inclusions. Muscovite overgrows the biotite foliation and the biotite is variably altered to chlorite and an opaque mineral; scattered, randomly oriented patches of intergrown muscovite and chlorite also occur. In the same area, the less micaceous layers primarily consist of plagioclase, quartz and biotite, and the brown-weathering layers similarly consist of plagioclase, quartz and a homogeneously distributed biotite mineral fabric. The quartz-rich layers contain quartz and scattered muscovite.

North of Sail dyke, the sillimanite-rich lenses consist of fibrolite clots containing scattered grains of biotite and an opaque mineral, and rare intersertal felsic grains. Fibrolite within the clots appears to define a relict foliation, preserved in strain-slip-type augen, which is overprinted by fibrolite, biotite and opaque minerals forming both a new foliation and randomly oriented growth. The clots are rimmed by biotite and commonly euhedral to subhedral opaque minerals. Biotite and opaque minerals are also heterogeneously distributed throughout the intervening quartzofeldspathic material, along with zircon and minor random growth of chlorite ± muscovite. In places, the clots appear to be partially disaggregated or assimilated.

A subarkosic psammitic paragneiss layer from north of Sail dyke consists of approximately 60 percent quartz, 30 percent plagioclase, 8 percent brown biotite, 2 to 3 percent muscovite, and traces of an opaque mineral, zircon and apatite. The biotite defines a strong foliation and optical orientation, whereas the felsic mineral fabric is weak and muscovite is isotropically distributed or mimetic.

Structure and Metamorphism

The paragneiss contains quartz or quartzofeldspathic leucocratic segregations subparallel to the layering. These veins and the thinner psammitic layers within the pelite are isoclinally folded; the mineral foliation is axial planar to these folds. The foliation developed at biotite and cordierite(?) grade, and the fibrolite inclusions are interpreted to represent an earlier, sillimanite-grade metamorphism. Refolding resulted in contorted patterns and crenulations but no penetrative mineral growth, although the axes of refolding are commonly approximately coplanar with rodding associated with the main mineral foliation (Plate 11). The growth of muscovite and chlorite, mostly at the expense of the large uncertain (?cordierite) porphyroblasts and biotite, respectively, was mimetic or random, representing postkinematic retrogression.

Contact Relationships

Southeast of Sail Lake, the pelitic paragneiss is intercalated with a layer of thin-bedded, volcaniclastic metasedimentary rock (subunit 1d) and flanked to the east by quartzite (subunit 1g); these relationships are assumed to be conformable. North of the Sail dyke, the subunit is intruded by tonalite dykes and sheets (subunit 2a) of the Sail Lake intrusive suite (Unit 2a). The boundary relationships of the main outcrop area are unknown.

Subunit 1g

Quartzite.

Distribution

The two main areas of this subunit occur near the western margin of the elongate Unit 1 outcrop area between Orma Lake and Duck Bay. They form 200 m-wide by 1- to 2-km-long layers trending subparallel to the belt. One occurs at the southern end, 2 km north of the Orma dyke; the other is 4 km south-southwest of Duck Bay. The remaining part of the subunit lies just west of the road, 3 km south-southwest of Proof Lake.

Description

The subunit is dominated by well-bedded white orthoquartzite containing thin pelitic laminae (Plate 12). The quartzite consists of tabular, 2- to 20-cm-thick, essentially plane-sided and parallel-laminated beds; crossbedding occurs rarely. The beds form cyclic groups, several metres thick, within which beds differ in average thickness from those in an adjacent group. The pelitic laminae are 0.5 to 2 cm thick and are muscovite rich. Rare, thin amphibolite or rusty pyritiferous layers are also present. The quartzite is intruded by subsequently deformed quartz and granitic veins. South-southwest of Proof Lake, the coarser grained clastic rocks are more arkosic. Quartz segregations are rarer; pyritiferous and gossanous zones are common.

Plate 12. *Quartzite with muscovite-bearing gritty laminae (subunit 1g). Photo and locality NN81-250, NTS 13L/3E, GR 8865.0140. Diameter of lens cap is 5.5 cm.*

Structure and Metamorphism

Both layers between Duck Bay and Orma Lake are vertical or overturned as determined from crossbedding or pillow structures in adjacent amphibolite (subunit 1a); younging is to the east. The quartz segregations and granitic veins are folded whereas the quartzite itself is generally only warped or exhibits mullions. The quartzite is recrystallized and the pelitic laminae contain a well-developed mica lineation. This fabric is coeval with the main fabric in the other subunits of Unit 1.

Contact Relationships

The quartzite is conformably interlayered in a sequence that includes amphibolite (subunit 1a) and thinly bedded volcaniclastic metasedimentary rock (subunit 1d) between Orma Lake and Duck Bay. Three kilometres south-southwest of Proof Lake, the subunit is assumed to have the same relationship with amphibolite (subunit 1a) and pelitic paragneiss (subunit 1f). Near Proof Lake, the subunit is intruded by granite (subunit 3c).

Sail Lake Intrusive Suite (Unit 2)

Foliated to gneissic granitoid rocks and pre- and syntectonic minor intrusions.

Definition and Division

Rocks defined here as the Sail Lake intrusive suite (Unit 2) were originally termed 'quartzofeldspathic gneiss' by Emslie (1964b) on the first map of the area, and subsequently 'quartzofeldspathic gneiss and granulite' (Emslie, 1970) where exposed, near the Michikamau Intrusion (Unit 10). Nunn and Noel (1982) named the suite 'Churchill Province gneisses' and described it as consisting of foliated to gneissic granitoid plutonic rocks. Preliminary age determinations (2663 Ma, Figure 7; Krogh, 1986) prompted Wardle *et al.* (1990) to name the area predominantly underlain by Unit 2 as the Orma Domain; follow-up dating (Late Archean ages on Figure 7; Nunn *et al.*, 1990) has confirmed the significance of the Orma Domain as an area of Archean crust, within the Churchill Province, in which the orthogneiss is the definitive unit. Unit 2 is given the informal name Sail Lake intrusive suite in this report.

The Sail Lake intrusive suite comprises a single region of approximately 1400 km². It forms a subrectangular block of about 30 km² in the centre of the north of the map area, and is flanked to the east by a strip 10 to 15 km wide that extends from the northern edge of the map area, in a south-southeasterly direction, to the southeastern corner of the map area (Map 93-19). About one quarter of the flanking zone consists of elongate and irregular patches of supracrustal rocks (Unit 1) and equant areas of plutonic rocks (Units 3 and 9). Large tracts of the northern area are unexposed and Unit 2 may similarly contain many (unrecognized) areas of other units in this region.

The suite is defined on the basis of lithology and age. It consists of a foliated to gneissic granitoid orthogneiss of predominantly tonalitic and granodioritic composition, and is of Late Archean age (dates of 2682 to 2663 Ma, Figure 7; Nunn *et al.*, 1990). The orthogneiss developed from a suite of granitoid plutonic rocks, mainly tonalite (subunits 2a, 2c and 2d) and granodiorite (subunits 2a, 2b and 2c) and subordinate diorite and quartz diorite (subunit 2a) or monzogranite (subunit 2e).

In addition to the compositional distinctions, subunits 2a and 2b are characterized by the replacement of formerly coarse, quartzofeldspathic grains by medium-grained, granoblastic, polycrystalline aggregates, and by variably developed, but commonly stromatic, leucocratic segregations. Conversely, subunit 2c lacks these aggregates and is typified by a generally finer grained, homogeneously distributed mineralogy, as well as abundant but generally diffuse and commonly discordant leucosomes. Subunits 2d and 2e are more homogeneous, exhibiting relatively few migmatitic features.

Unit 2 includes a host of pre- to syntectonic dykes (subunit 2f) of mafic to felsic composition, and synplutonic and/or syntectonic granitoid sheets, dykes and veins (subunit 2g) that occur throughout the unit.

Age

Emslie (1970) assigned a questionably Archean age to his quartzofeldspathic gneiss, granulite and migmatite complex.

Four samples of foliated tonalite or tonalite paleosome from variably migmatitic tonalitic orthogneiss have been analyzed for U–Pb age determinations from zircon and titanite (Figure 7). The upper intercept dates from the zircon fall in the range 2682 ± 7 Ma to 2663 $^{+4}_{-3}$ Ma (Nunn *et al.*, 1990). Study of the zircon fractions suggests a single, euhedral, magmatic population, which therefore, clearly defines a Late Archean emplacement age (Krogh, 1986; Nunn *et al.*, 1990).

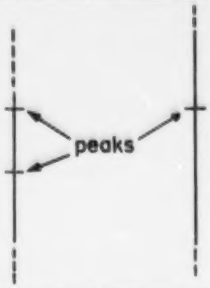
Subunit 2a

Foliated to gneissic tonalite and minor granodiorite, quartz diorite and diorite.

Distribution

Subunit 2a dominates the eastern areas of the Sail Lake intrusive suite, underlying, in particular, about 90 km² to the north, northeast and southeast of Sail Lake, about 50 km² between Duck Bay and Orma Lake (west of the Unit 1 outcrop area), about 40 km² east of Orma Lake, and some 80 km² from Fremont Lake east and southeastward to the edge of the map area. All of these areas are subequant to slightly elongated (generally northerly) and contain very irregular margins. Outcrops and small areas of subunit 2a also occur

Table 2. Generalized intrusive sequence for subunit 2a (mainly developed in the area around Orma dyke and best seen in the spillway below the dyke), parts of which are found throughout the subunit, illustrating its polyphase and syntectonic nature

Unit/Subunit	Unit 2 phases	Enclaves	Felsic vein sets	Deformation
Unit 3				
Intrusive contact				
Subunit 2g	Pink granite dykes			
Subunit 2a	Younger granodiorite Older granodiorites Orma dyke tonalite Older tonalite Early quartz diorite	Quartz diorite, diorite, tonalite and amphibolite xenoliths		
Intrusive contact				
Unit 1				

north, south and east of Kasheshibaw Lake and in Fraser Lake (in areas mostly underlain by subunit 2b), and in the area north of Duck Bay.

Description

Subunit 2a is a polyphase group of intrusive rocks ranging in composition from diorite to granodiorite (Table 2). Primary structures in the subunit relate mostly to the polyphase nature, and consist of either inclusions (Plate 13), strips, schlieren, screens and rafts of older rock types, or sheets (Plate 14), dykes, veins, apophyses and other irregular patches of younger phases. The inclusions are centimetres to tens of metres long and usually elongate, ranging from oval to tabular or very flattened. They include, in places, decimetre-size to map-scale enclaves of supracrustal rocks (Unit 1) and disrupted, younger dykes. Sheets and dykes are normally centimetres to half a metre wide, but range up to several metres. Rafts of older phases and irregular intrusive bodies of the younger rock types range up to outcrop scale.

The most voluminous phase, referred to here as the Orma dyke tonalite, is the third phase in the intrusive sequence for subunit 2a but will be described first due to its areal importance. It is medium to dark grey on fresh surfaces and cream-to-buff, or more rarely, light-grey weathering. The rock is fine to medium grained and typically consists of aggregates of quartz, plagioclase or both that indicate an original medium to coarse grain size. The tonalite has quartz contents that range from 15 to 50 percent (generally 20 to 30 percent), plagioclase of 45 to 75 percent and rare occurrences of K-feldspar of less than 10 percent. Some particularly K-feldspar-rich or quartz-poor compositions from these ranges fall in the granodiorite and quartz–diorite fields, respectively, but are rare. The colour index is in the range 8 to 25 (normally 10 to 15), and is defined by hornblende, biotite, magnetite and chlorite. Hornblende may exceed biotite or vice versa; but whereas biotite commonly occurs without hornblende, the latter rarely occurs alone. Epidote, muscovite, sulphide and garnet are present locally.

Plate 13. *Older granodiorite sheet (light beneath clinometer) intruding various light, medium and dark grey, pre-Orma dyke tonalite phases (rest of picture); (subunit 2a). Photo GN84-CS44-3, locality G817, NTS 13L/3E, GR 8940-9816. Length of clinometer is 10 cm.*

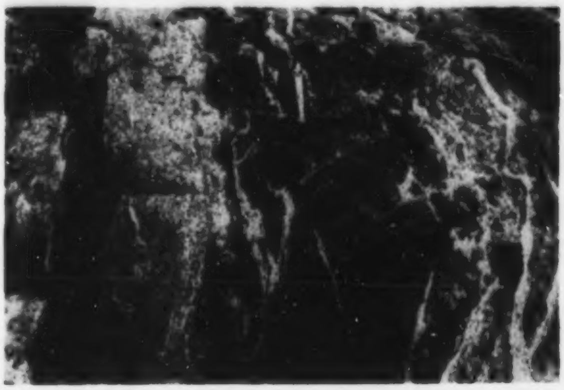


Plate 14. *Early quartz diorite (centre) and older tonalite (left) screens containing three sheets of Orma dyke tonalite (subunit 2a). Photo GN80-CS21-22, locality G458b, NTS 13L/3E, GR 8909.9726. Length of hammer is 34 cm.*

The Orma dyke tonalite contains a predominantly metamorphic mineralogy exhibiting a range of blastic textures. Mostly these are equigranular, equant and commonly polygonal, but may be elongate on a mineral or aggregate scale. Granoblastic recrystallization of elongated aggregates is typical. The ferromagnesian minerals occur between the quartzofeldspathic aggregates, and abundant biotite defines anastomosing foliae around them. The textures commonly include inequigranular porphyroblastic or porphyroclastic features, the former commonly of hornblende and biotite and rarely of plagioclase and magnetite, and the latter commonly of plagioclase and rarely of hornblende. In hand specimen, plagioclase is the only relict mineral of an earlier coarser grain size; the tonalite appears, originally, to have been either equigranular or plagioclase (and possibly hornblende) porphyritic.

The tonalite is foliated and quartzofeldspathic aggregates are strongly rodded in places. Leucocratic segregations constitute a minor to a major component of the rock and are concordant or discordant (Plate 15). Concordant segregations are parallel or subparallel to the foliation and consist of white to light-grey, centimetre- to decimetre-wide veins of tonalite. These veins have indistinct margins and a very low colour index (less than 5); the veins form 5 to 60 percent (generally 20 to 30 percent) of the rock. The concordant veins have the same grain size and textural characteristics as the host tonalite. On islands in south-central Kasheshibaw Lake, these veins are accentuated locally by intrusion of subparallel sheets of centimetre- to metre-scale granite and monzogranite, and concordant veins form up to 80 percent of the rock. The sheets locally contain a similar aggregate texture to the host tonalite, or are more homogeneous.

Plate 15. *Orma dyke tonalite intruded by granite sheet (subunit 2a). Deformation caused foliation development in the tonalite and folding with axial planar foliation in the sheet (right); further deformation necked the granite sheet and caused foliated tonalite to flow into the pinches. Photo GN81-CP42-1, locality G807b, NTS 13L/3E, GR 9106.0074. Length of hammer is 45 cm.*

Discordant segregations consists of either i), yellow- to cream-weathering, light-grey felsic veins, sheets and dykes (Plate 15) of irregular thickness and orientation (generally with a very low colour index of 0 to 3) or ii), diffuse patches. The discordant patches contain more abundant ferromagnesian porphyroblasts (hornblende, biotite or magnetite) than the veins, and the colour index ranges up to 15. Textures are otherwise similar to the host tonalite, but quartzofeldspathic aggregates are both less obvious, due to the low biotite content, and less abundant, and indicate that fine grained, homogeneous protoliths were more common in the veins than in the host tonalite. Discordant veins are generally folded; they range from minor to up to 50 percent of the outcrop. Some of this veining relates to the emplacement of younger phases within the subunit than the Orma dyke tonalite.

The main variations in the Orma dyke tonalite consist of originally fine to medium grain sizes (represented by smaller aggregate sizes), homogeneous rocks containing no aggregates, a low colour index (3 to 8), low quartz contents ranging decreasingly into quartz diorite compositions, and variation in the intensity of elongation of the aggregates and of the type and abundance of leucosomes (as noted earlier). The structural variations are common; variations relating to grain size, texture and composition are rare. Variations occur throughout the subunit but the non-structural types are locally more abundant in the northeast of the map area.

The remaining phases of subunit 2a are described, approximately, in a chronological order (Table 2). Locally, either older or younger phases may be more abundant in an outcrop or group of outcrops than other phases in the sequence, including the Orma dyke tonalite. The chronological sequence is defined in the area of abundant clean outcrop beneath and east of the Orma dyke. Parts of the polyphase nature of the sequence are found elsewhere in the subunit but seem much less common (this feature may be more apparent than real due to poor exposure).

Enclaves of amphibolite are common and are provisionally assigned to subunits 1a and 1b. They are light to dark grey, dark green or black, fine grained and metamorphic textured. Several are layered and/or plagioclase porphyritic and range from leucoamphibolite to hornblendite. Some may be disrupted dykes. Metasedimentary enclaves of subunit 1d occur in the Fremont Lake area but are rare.

Equally common, are enclaves of light- to dark-grey, fine-grained, metamorphic-textured diorite, leucodiorite, quartz diorite and tonalite (Plate 13). They are either homogeneous, or plagioclase and/or hornblende porphyritic, and exhibit a large range in colour index. The phenocrysts are replaced locally by fine-grained, granular aggregates. Biotite is the main ferromagnesian mineral and, along with any aggregates, commonly defines a foliation. The felsic minerals generally display equant crystallization. These dioritic enclaves are known only to predate the Orma dyke tonalite and they may be partly equivalent to other pre-tonalite phases; some may also be disrupted dykes.

A dark-grey to black, light- to dark-grey-weathering, fine- to medium-grained quartz diorite to tonalite is the oldest defined intrusive phase in subunit 2a. The rock has a colour index of 25 to 45, defined by hornblende ± biotite, locally is plagioclase or hornblende porphyritic, and is massive to weakly foliated. This phase is rare and always occurs in association with, or close to, amphibolite of subunits 1a and 1b, which it intrudes in an irregular manner. It is intruded by biotite tonalite of the next phase and occurs as rare screens and inclusions in the Orma dyke tonalite (Plate 14).

The next phase in this intrusive sequence is a medium- to dark-grey, medium-grey-weathering biotite tonalite. It is fine grained and mostly exhibits an equant granoblastic texture containing a biotite foliation. In one place, porphyroblasts and diffuse clots of fine-grained garnet up to several millimetres across are surrounded by centimetre-sized quartzofeldspathic haloes that have oval to equant cross-sections. In the area around Orma dyke and to the south-southeast of Orma Lake, the biotite tonalite is characterized by an abundant centimetre-scale felsic layering (Plate 16). The felsic layering is light grey, of very low colour index, folded (commonly isoclinally) and strongly foliated. The foliation is defined in places by a strong rodding, which also occurs in the discordant felsic veins that are usually present. Elsewhere, this tonalite either contains less abundant, diffuse or discontinuous, felsic migmatitic layering or is homogeneous except for rare random veins. This phase occurs as sheets and dykes in amphibolite of subunits 1a and 1b, intrudes the previous phase, and is sheeted by, or enclosed in, the Orma dyke tonalite (Plate 17).

Plate 16. *Older tonalite (subunit 2a) containing characteristic pretectonic felsic veins that have been isoclinally folded and rodded during the main foliation-forming episode of deformation. Photo GN80-CS20-32, locality G443b, NTS 13L/3E, GR 8905.9686. Length of clinometer is 10 cm.*

The Orma dyke tonalite contains numerous enclaves of amphibolite, dioritic rocks and the biotite tonalite phase, and less abundant inclusions of the quartz diorite phase of subunit 2a (all described above).

Plate 17. *Orma dyke tonalite (subunit 2a) containing large enclaves of older tonalite – note characteristic felsic veining in the older tonalite. Photo GN80-CS21-16, locality G458a, NTS 13L/3E, GR 8925.9715. Length of hammer is 34 cm.*

Several phases of fine-grained homogeneous granodiorite postdate the Orma dyke tonalite. These phases are all medium to dark grey on fresh surfaces, but weather to white, cream and light or medium grey. Quartzofeldspathic minerals form individual grains or polygonal aggregates, which are strongly rodded in places (Plate 18). Biotite is homogeneously distributed and defines a mineral fabric, but is absent from felsic haloes that are present around some magnetite porphyroblasts. Stromatic leucosomes are absent but random, wavy to folded felsic veins are common.

These different granodiorite phases are recognizable in the field only by variations in the weathering colour, which may be fairly subtle. Beneath the Orma dyke alongside the overflow channel, a white-weathering phase crosscuts the contacts of a grey phase and the Orma dyke tonalite. In the quarry 0.5 km east of the north end of the Orma dyke, a brownish-weathering phase and two grey phases are present but relationships are less clear cut; any one of the phases appears to contain an abundance of xenoliths of one of the other two. They intrude the main Orma dyke tonalite phase as irregular sheets and dykes.

A light- to medium-grey, cream- to buff-weathering, formerly medium- to coarse-grained granodiorite is the last phase in the subunit 2a intrusive sequence. It is similar in appearance to the Orma dyke tonalite and characterized by the same quartzofeldspathic aggregates, biotite foliation and finer grained recrystallization; however, the colour index is

Plate 18. *Strongly rodded older granodiorite (subunit 2a). Photo GN80-CS21-13, locality G458a, NTS 13L/3E, GR 8925.9715. Length of hammer is 34 cm.*

less than the average for the Orma dyke tonalite phase and the aggregates are less strongly rodded. This granodiorite contains biotite ± hornblende and magnetite, all three of which are locally porphyroblastic. The phase is rare and positively recognized only near the Orma dyke. There it forms irregular sheets in the earlier granodiorite phases, the Orma dyke tonalite and the leucosome-layered, dark-grey biotite tonalite, against which a finer grained marginal facies is locally developed.

Suites of yellow-, cream- and buff-weathering felsic veins occur in most of these rock types and can be shown to be of several (possibly continuous) generations throughout the subunit 2a sequence. They vary from stromatic to venitic and rarely agmatitic, and from sparse to abundant. The veins consist of either a plagioclase–quartz or a plagioclase–K-feldspar–quartz felsic mineralogy, which is locally quartz rich, and a colour index of 0 to 10 defined mostly by clots of hornblende, biotite or magnetite and wispy, foliation-parallel schlieren of biotite. They are commonly very irregular in orientation, size (millimetre to metre scale), thickness and grain size, although fine-grained, granoblastic polygonal textures predominate. These irregularities (Plate 15) are mostly due to deformation: most veins are folded, from wavy through asymmetric to isoclinal forms, or are necked and boudined. Veins commonly are associated with the locus of shear zones, fold axial planes and attenuated fold limbs. The suite of less deformed, but generally pre- to syntectonic, pink, aplitic to pegmatitic sheets, dykes and veins (characteristic of subunit 2g) is ubiquitous though sparse in number.

Petrography

The assemblage plagioclase + quartz ± microcline + biotite ± hornblende + opaque minerals ± titanite ± muscovite constitutes the essential mineralogy of the Orma dyke tonalite. Quartz is rarely more abundant than plagioclase and, where present, hornblende is commonly greater than or equal to biotite. Titanite is a conspicuous minor component in most rocks, and allanite, zircon and apatite are invariably present in accessory amounts. Some biotite contains exsolution lamellae of an opaque mineral, and allanite is commonly rimmed by epidote. Muscovite is more common in the Kasheshibaw Lake area than elsewhere.

Plagioclase and hornblende megacrysts either occur as relict single grains or are replaced by blastic aggregates of the same phase. They sit in a matrix of irregularly shaped quartz patches, ferromagnesian patches, and a more homogeneous mixture of quartz + plagioclase ± microcline containing scattered individual ferromagnesian minerals. Aggregate sizes vary: large aggregates, 4 to 7 mm across, are internally composed of 0.2 to 0.5 mm and up to 1 mm grains, whereas in the groundmass, quartz and ferromagnesian patches of 1 to 3 mm across are recrystallized to 0.2 to 0.5 mm grains, as are homogeneous rock types. The large aggregates, and similarly sized relict crystals, are probably close to the original phenocryst grain sizes, whereas the matrix patches probably represent the original groundmass grain size; the smaller crystal sizes are largely the result of metamorphic crystallization. The metamorphic blastic textures range from polygonal to anhedral, from equigranular to inequigranular, and from equant to elongate.

The foliation is defined by elongated porphyroclasts, groundmass quartz, monomineralic and polymineralic aggregates, and mineral fabrics of hornblende, biotite, muscovite and, to a lesser degree, epidote, titanite, opaque minerals and felsic minerals. Aggregate crystallization is mainly syntectonic but some may be posttectonic. Other posttectonic crystallization consists of randomly oriented biotite and, perhaps, some hornblende poikiloblasts. Subsequent retrogression or alteration is represented by saussuritization of plagioclase, chlorite and muscovite replacement of biotite, and scattered development of epidote, chlorite and muscovite. Epidote and muscovite are both foliation-forming and secondary minerals, and the secondary crystallization is both mimetic and random. Replacement of the foliation-forming minerals, however, is rarely pervasive.

The biotite tonalite that predates the Orma dyke tonalite contains an earlier foliation that is truncated by the later of the granodiorite phases in this subunit. The earlier foliation occurs in small, mainly quartzofeldspathic augen enclosed by a younger foliation which is only slightly oblique to the contact and occurs in both phases. In the biotite tonalite, the younger foliation is defined by a mineral fabric of biotite ± an opaque mineral ± titanite that is distributed throughout the largely subequant felsic minerals, by rare streaky clots of biotite + epidote + plagioclase, and by a diffuse felsic location fabric, which contains scattered porphyroblasts of an opaque mineral. Both foliations anastomose around coarse-grained, relict plagioclase; the earlier as a biotite mineral fabric and a weak mortar texture, and the later as a coarser, granular, felsic fabric and ferromagnesian recrystallization. Green biotite is characteristic of both foliations at this locality.

The earlier granodiorite phases that postdate the Orma dyke tonalite contain intergranular microcline. The foliation is defined by biotite, opaque minerals and epidote mineral fabrics, and by relatively K-feldspar-rich (monzogranite) lenses. The later granodiorite phase (and the last phase in the subunit 2a intrusive sequence) contains larger grains of perthitic microcline, which is commonly corroded by myrmekite. Its foliation is defined by quartzofeldspathic aggregates and biotite, epidote, titanite and opaque minerals. The rock also contains mimetic or randomly oriented porphyroblastic biotite clots, opaque minerals and epidote.

On islands in south-central Kasheshibaw Lake, thick granite and monzogranite sheets intrude the gneiss. Either microcline or quartz is the dominant felsic mineral, and they occur as foliated aggregates. Muscovite–green biotite–epidote–hematite ± garnet constitute the remainder of the foliation-forming assemblage. Chlorite randomly replaces biotite and muscovite.

Structure and Metamorphism

The most prominent tectonic features in subunit 2a are the leucocratic segregations, especially where they are abundant and more or less concordant (e.g., Plates 15 and 16), and the quartzofeldspathic shape fabrics (Plate 18). The veins are the result of several episodes of intrusion or development; the shape fabrics are largely due to the main foliation formation.

The main foliation is defined by a variety of features: a biotite mineral fabric and biotite-rich schlieren and foliae; an anastomosing ferromagnesian foliation; minor quartzofeldspathic and hornblende mineral fabrics; subparallel to concordant migmatite location fabrics; enclave orientation; and a strong felsic shape fabric. The migmatite location fabrics consist of the low-colour-index stromatic veins with diffuse margins in the Orma dyke tonalite, and tightly folded or strongly rotated, mainly earlier, felsic veins throughout the sequence. Locally the stromatic veins are earlier too, such that much of the felsic veining enhances the foliation due to extreme deformation and folding rather than synchronous migmatite development. The felsic aggregates range in shape from stumpy discs to rods with aspect ratios of over 20:1. During the main foliation development, stronger or localized deformation zones have resulted in porphyroclastic textures that preserve coarser grained relict plagioclase.

All of the vein sets and intrusive phases have been affected by the main deformation, although the last granodiorite phase contains less elongated quartzofeldspathic aggregates than the adjacent Orma dyke tonalite and earlier granodiorite phases. Later generations of the felsic veins (and of the pink granitic dykes of subunit 2g, see below) are locally less tightly folded or less strongly foliated than earlier generations.

The development of porphyroblastic plagioclase and ferromagnesian minerals is assumed to be syn- to posttectonic with respect to the main foliation. Hornblende and biotite locally form a lineation parallel to the felsic rodding and are syntectonic in these cases. Plagioclase morphology prevents determination of its relationship to the main foliation, and random hornblende and clots of biotite are probably posttectonic. Garnet and magnetite show little or no mineral alignment, and their weak, triaxial, felsic haloes could indicate either late syntectonic or mimetic posttectonic crystallization. Main foliation and posttectonic crystallization include hornblende, biotite, titanite, opaque minerals, epidote and garnet, and, locally only, muscovite, as potential index minerals.

Features earlier than those associated with the main foliation are relatively few. Relict minerals are present as plagioclase porphyroclasts; geochronological analysis of the Orma dyke tonalite indicates the presence of relict zircon as well (Krogh, 1986). Both minerals are thought to be magmatic grains. Mineral or shape fabrics that predate the main mineral recrystallization are very rare. Adjacent to the road to the northeast of the Fremont dyke, 2.5 km from the Orma dyke, and in the outflow beneath the Orma dyke, earlier structures are preserved as augen and relicts in a younger anastomosing or strain-slip foliation. The deformed leucocratic segregations represent several generations developed between or throughout emplacement of the various phases of subunit 2a (Table 2). At least some of those in the early biotite tonalite predate the emplacement of the Orma dyke tonalite and hence also predate the main foliation.

The main foliation is deformed by later folding events. Tight to asymmetric folds of the foliation and its related felsic location fabrics are mirrored internally in some of the thicker felsic sheets (e.g., in the granite sheets in south-central Kasheshibaw Lake) by the development of chevron folds. Rarely, a weak axial-planar fracture fabric or biotite mineral fabric is developed in the fold hinges; usually, there is no associated fabric development. These folds have been refolded to form outcrop- to map-scale interference structures, small-scale shear-zone-type folding with or without leucocratic segregations, and open folds or warps. The relative timing of the last three deformations is unknown.

Post-main-foliation and post-peak-metamorphic mineral growth is marked by granular epidote crystallization and chloritization of biotite, minor muscovite, and mineralization of joints and fractures by epidote, chlorite and quartz ± calcite.

Contact Relationships

The Orma dyke tonalite and earlier phases of subunit 2a intrude amphibolite (subunit 1a), metagabbro (subunit 1b), tuff and metasedimentary rock (subunit 1d) and pelitic paragneiss (subunit 1f).

Granodioritic orthogneiss (subunit 2b) appears to have similar relationships to the structural and metamorphic events in the map area as has the Orma dyke tonalite and is regarded as an approximately coeval compositional variant, although rare inclusions of tonalitic gneiss occurring in the granodioritic orthogneiss could be part of the Orma dyke tonalite. Locally, subunit 2a appears gradational into finer grained, diffusely and more randomly migmatized orthogneiss (subunit 2c), and some ferromagnesian-spotted migmatite veins and patches in the Orma dyke tonalite are similar to subunit 2d. Contact relationships with granites of subunit 2e are not exposed and mafic dykes of subunit 2f are not common, whereas pink granitic dykes of subunit 2g are ubiquitous.

Subunit 2a is intruded by granitoid rocks (subunit 3c, north of Duck Bay, and subunits 9c and 9d, between Orma and Marie lakes) and is in fault contact with the Seal Lake Group (Unit 11) in the east of the map area.

Subunit 2b

Foliated to gneissic granodiorite, quartz monzonite and monzogranite.

Distribution

Subunit 2b forms most (approximately 700 km²) of the Unit 2 outcrop area in and around the northern areas of the reservoir (Kasheshibaw and Sail lakes), and from Kasheshibaw Lake west to Hook Lake and northwest to Fraser Lake and the map boundary. A very poorly exposed equant area of approximately 40 km² occurs east of the outcrop area of the supracrustal rocks (Unit 1) between Orma Lake and Duck Bay. Smaller areas and individual outcrops occur widely scattered in areas assigned to tonalitic orthogneiss of subunit 2a.

Description

Subunit 2b consists of two major granodioritic rock types, a number of subsidiary ones and, like the tonalitic orthogneiss of subunit 2a, a variety of inclusion types and numerous felsic veins. The various phases are all more or less granodioritic, but contact relationships between them are unknown and it has not been possible to establish a relative chronology (except in relation to the inclusions and veins, which show similar size and shape of intrusive characteristics as those noted for subunit 2a).

Plate 19. *Augen texture in foliated, K-feldspar-megacrystic biotite granodiorite (subunit 2b). Photo and locality NN81-376, NTS 13L/6W, GR 6898.2136. Diameter of lens cap is 5.5 cm.*

The most extensive rock type occurs throughout the Kasheshibaw Lake area. It is a dark-grey, buff- to grey-weathering, K-feldspar-porphyritic granodiorite (Plate 19). The groundmass is composed of inequigranular but fine-grained granoblastic quartz, plagioclase, biotite and K-feldspar (± hornblende), which are homogeneously distributed or present as very indistinct aggregates. The groundmass encloses porphyroclastic grains of grey or white K-feldspar, quartz, plagioclase and oligomineralic quartzofeldspathic mixtures, and porphyroblastic and/or porphyroclastic hornblende. These relicts indicate an original groundmass grain size of greater than 5 mm and porphyritic K-feldspar of 1.5 cm or more, although most porphyroclastic grains are only 3 to 6 mm across (Plate 20). The sizes, concentrations and distribution of the porphyroclasts are very irregular, but in rare examples a diffuse and generally discontinuous layering is exhibited. K-feldspar is rare in the groundmass and plagioclase is rare as porphyroclasts, indicating a granodioritic composition. Greater amounts of K-feldspar in the groundmass or lesser amounts of porphyritic K-feldspar may put some compositions in the monzogranite and tonalite fields, respectively; quartz monzodiorite or quartz monzonite, due to lesser amounts of quartz, are also present.

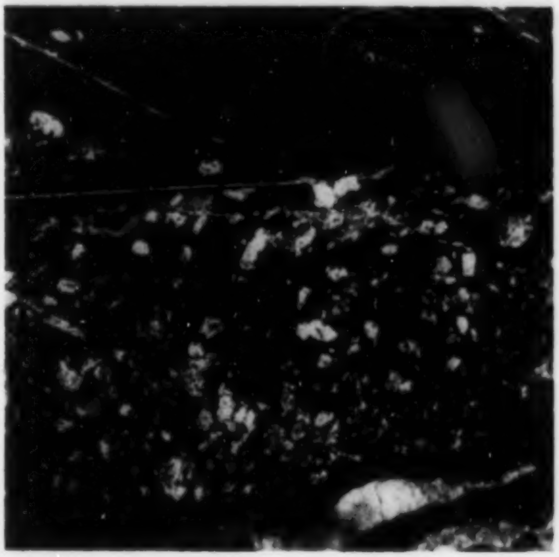


Plate 20. *Tectonic inclusion of foliated, augen-textured, K-feldspar-megacrystic biotite granodiorite in migmatitic, porphyroclastic-textured granodiorite developed from the inclusion lithotype by more extreme deformation (subunit 2b). Photo and locality NN81-377, NTS 13L/6W, GR 6853.2132. Diameter of lens cap is 5.5 cm.*

The colour index, defined mostly by biotite ± hornblende, is 2 to 10 and generally less than that in the Orma dyke tonalite (subunit 2a).

The rock is variably foliated: a biotite mineral fabric and felsic shape fabric occur in the groundmass and there is a rare orientation of elongate porphyroclasts. Most porphyroclasts are equant and most felsic minerals are polygonally recrystallized. Locally, the fabric grades into mylonite containing quartz ribbons, elongate fine-grained aggregates of feldspar and a platey structure. Between Kasheshibaw and Sail lakes, large areas occur that contain minor stromatic or random migmatite veins, whereas in the west of Kasheshibaw Lake, leucosomes are more common. In central areas of the lake, leucocratic segregations are dominant and have coalesced to form a diatexite containing paleosome relicts and biotite-rich schlieren (Plate 21). The coalesced migmatite veins are very irregular in thickness and seriate textured (Plate 22). Commonly they appear to contain the grey feldspar porphyroclasts (some show an irregular white rim), which are scattered or clustered in a matrix of predominantly grey quartz. Isoclines and other folds of this migmatite are common (Plate 21).

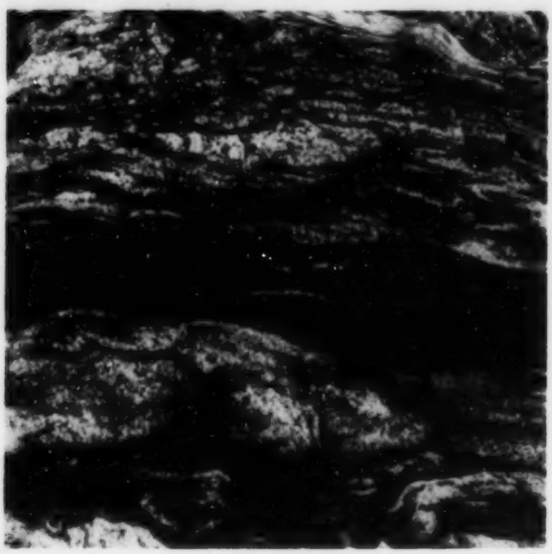


Plate 21. *Screen of strongly deformed, weakly migmatized metatexite surrounded by diatexite, both of which were derived from the same granodiorite gneiss (subunit 2b). Photo and locality NN81-373, NTS 13L/6W, GR 7224.2265. Diameter of lens cap is 5.5 cm.*

Other, largely discordant, felsic vein sets, similar to those in subunit 2a, are common throughout the western parts of Kasheshibaw Lake. Here, also, pink, aplitic, granitic and pegmatitic dykes and veins of subunit 2g, late, commonly quartz-rich veins, and mineralized fractures and veins of epidote are common. Where thin quartz- and/or epidote-filled veins and gashes are abundant, the outcrops are marked by a profusion of minor displacements.

Plate 22. *Strongly deformed granodiorite gneiss containing discordant diatexite veins (subunit 2b). Photo and locality NN81-374, NTS 13L/6W, GR 7215.2300. Diameter of lens cap is 5.5 cm.*

The second major rock type is a grey, cream- to buff-weathering, fine- to medium-grained granodiorite that occurs throughout the eastern parts of the subunit 2b outcrop areas and also north and southwest of Fraser Lake. It typically consists of quartzofeldspathic aggregates indicating an originally medium to coarse grain size. The aggregates are similar in shape and size to the Orma dyke tonalite, but the anastomosing biotite foliation is much less prominent reflecting the generally lower colour index (2 to 10). The K-feldspar contents are commonly uncertain and the rock may range from tonalite (i.e., equivalent to a low colour index Orma dyke tonalite) to monzogranite. Hornblende is not common, biotite is locally chloritized and muscovite is also present in some rocks. Locally, titanite occurs as sphenoidal euhedra, up to 0.5 by 1.5 mm across, orientated parallel to the foliation, and biotite and magnetite are porphyroblastic. North and southwest of Fraser Lake, the granodiorite gneiss is statically recrystallized and spotted with posttectonic clots of fresh, black biotite ± brown-weathering orthopyroxene for up to 2 or 3 km from the Michikamau Intrusion (Unit 10).

The felsic aggregates are composed of equigranular, equant and commonly polygonal minerals but include rare porphyroclastic plagioclase and K-feldspar, generally in zones of otherwise finer grain sizes. These may have been porphyritic grains in the granodiorite protolith. Leucocratic veins are ubiquitous, showing the same minor to major abundance and concordant to discordant relationships as that in the Orma dyke tonalite (subunit 2a). Smaller sized aggregates and homogeneous rocks exhibiting no shape fabric, as well as finer grained zones of more intense deformation and porphyroclastic texture, are the other main variations in the petrology of subunit 2b. Felsic vein sets and the pink, aplitic to granitic veins of subunit 2g occur throughout.

A very heterogeneous group of commonly white-weathering rocks is exposed in the southwest corner of the Unit 2 area between granitic rocks of subunit 2e and Contact Lake. The bulk of the rock is very strongly foliated, fine grained, sugary textured and white or light grey, and has a platey structure defined by recrystallized quartz ribbons or feldspathic aggregates, commonly with a muscovite-bearing micaceous parting. The rock is interpreted as a recrystallized mylonite. It also has a gentle, undulating foliation and a shallowly plunging aggregate lineation. Less deformed and heterogeneous patches having coarser grain sizes are common. Some are quartz and/or K-feldspar rich, pinkish, and range up to pegmatitic in grain size; these represent dismembered granite dykes of subunit 2g that now form strain augen. Other augen consist of migmatite-layered orthogneiss or mixtures of orthogneiss and the disrupted granite. The layered gneiss appears to be granodioritic in composition and, therefore, has been assigned to subunit 2b.

Enclaves of amphibolite (subunits 1a and 1b) are less numerous in the granodioritic orthogneiss than they are in the tonalitic orthogneiss (subunit 2a). Near Hook Lake, enclaves of Unit 1 amphibolite are in pyroxene-hornfels facies. Grey, fine-grained dioritic and tonalitic enclaves are, however, common. They are granoblastic textured, homogeneous or migmatitic, and commonly plagioclase porphyritic. These inclusions are similar to those occurring in the Orma dyke tonalite, although the strongly migmatitic, dark-grey, 'earlier tonalite' type (e.g., Plate 16) is rare. The main phase of subunit 2b contains rare, stromatic tonalite gneiss enclaves that resemble the Orma dyke tonalite.

Petrography

Plagioclase is predominant over quartz in the Kasheshibaw Lake area, and the K-feldspar is represented by relict megacrysts. These porphyroclasts are weakly to moderately aligned and occur in an inequigranular, anhedral to polygonal, blastic groundmass; the foliation is defined by mineral fabrics of biotite ± hornblende + epidote + an opaque mineral ± titanite and by quartz ribbons. Titanite is euhedral or anhedral and is commonly associated with, or forms rims around, the opaque mineral. Zircon ± allanite ± apatite are accessory phases. The allanite commonly has epidote rims and vice versa. Epidote, chlorite and muscovite are the main secondary minerals and occur as granular, mimetic and random overprints, respectively. Epidote also commonly occurs at the grain boundaries between feldspar and other grains, and, with muscovite, as coarse-grained saussuritization of plagioclase.

In the east of the map area, the granodioritic rocks are texturally very similar to the Orma dyke tonalite. They differ mainly in that the granodiorite has a generally lower colour index, more microcline and more granitic leucosomes. The non-felsic assemblage consists of green biotite, opaque minerals, chlorite, titanite, epidote and very rare hornblende. Apatite, zircon and possibly monazite occur as accessory minerals. Titanite is commonly pleochroic; more rarely, it exhibits euhedral overgrowths on less regular cores.

Leucosomes are variously dominated by plagioclase, quartz or microcline. Typically, quartz-rich leucosomes contain up to 20 percent intergranular microcline ± minor plagioclase. The host colour index is generally less than 10 and that of the leucosomes less than 5.

Most non-felsic minerals, together with felsic aggregates, define a well-developed to moderate foliation, whereas individual felsic minerals display a poor mineral fabric. Chlorite mimetically overprints the foliation, and muscovite occurs as a random, posttectonic overprint.

Structure and Metamorphism

The main foliation in subunit 2b in the east of the map area is defined by felsic shape aggregates, a biotite and weak felsic mineral fabric, variably developed migmatite location fabrics, and enclave orientations. Earlier structures consist of felsic vein sets, and composite structures that are similar to those in nearby tonalite (see above, pre-main foliation features for subunit 2a) occur by the road northeast of the Fremont dykes, 3.5 km from the Orma dyke. Later structures consist primarily of folds, shear zones, local leucosome development, and fracturing. This is the same style and sequence of structures as that developed in the tonalitic orthogneiss (subunit 2a), including the same conditions of deformation and metamorphism which produced similar mineral assemblages and relationships. The more K-feldspar-rich veins and plutonic rocks commonly contain muscovite as well as biotite as a foliation-forming mineral; this is also true for zones of greater deformation (shear zones and areas of more porphyroclastic texture). The east-northeast-trending fault system shown on the map southeast of Duck Bay contains fractures cemented by carbonate and chlorite. Greenschist-facies alteration is also common near the north-northwest-trending faults at the contact with the Seal Lake Group (Unit 11).

In the K-feldspar-porphyritic phase, the main foliation is represented by a biotite mineral fabric (Plate 19), a weak felsic mineral and shape fabric, and pre- to syntectonic stromatic migmatite location fabrics (Plate 21). Other fabric delineators include folded or rotated veins, enclave elongations, biotite-rich schlieren, a weak porphyroclast orientation (Plate 19), and a variably developed deformation-induced layering defined by grain size (e.g., the paleosome in Plate 22) and porphyroclast concentration. Quartz ribbons and platey structures locally characterize mylonite zones. Leucocratic segregations and biotite, hornblende and titanite, ± muscovite and epidote, are the chief indicators of the metamorphic grade of the main foliation. Earlier structures are confined to veins in enclaves and to foliation in tectonic inclusions of (closer to) protolith material, although the latter may be related to localization of progressive deformation; later folding is the same as that in the tonalitic orthogneiss (subunit 2a). Quartz, epidote, chlorite and pink-stained feldspar, all mostly associated with fracturing, are evidence of post-peak-metamorphic retrogression.

The mylonite near Contact Lake postdates the gneissic layering, the emplacement of subunit 2g granite and pegmatite dykes and, at least in part, the main-foliation features found in augen within the mylonite. Development of the mylonite was followed by a major static recrystallization resulting in the saccharoidal texture of the rock.

Contact Relationships

The granodiorites contain enclaves of Unit 1 amphibolite in the western parts of Kasheshibaw Lake. Internal contact relationships within subunit 2b were not seen except for the grey dioritic and tonalitic enclaves, which are xenoliths. The granodioritic gneisses appear to be structurally and texturally the coeval equivalents of the tonalitic orthogneiss (subunit 2a), differing only in mineralogy. Locally, however, inclusions resembling Orma dyke tonalite are found in the K-feldspar-porphyritic phase of subunit 2b in western parts of Kasheshibaw Lake. Relationships between subunit 2b and the foliated to gneissic granitoid rocks of subunits 2c and 2d are unknown. Subunit 2e granite is intrusive into the granodiorite gneiss and contains tabular rafts and inclusions of the gneiss in the centre of Kasheshibaw Lake. Mafic (subunit 2f) and granitic (subunit 2g) rocks both form dykes in the various granodiorite phases.

Rocks of the Petscapiskau Group (Unit 5) appear to be thrust, approximately northeastward, over orthogneiss along the mylonite near Contact Lake. The orthogneiss may be thrust over granite (subunit 2e) along this same mylonite zone.

Subunit 2b is intruded by the Michikamau Intrusion (Unit 10) in, and north and southwest of, Fraser Lake. Close to this boundary, it is contact metamorphosed to pyroxene-hornfels facies. In the east of the map area, subunit 2b is in fault contact with the Seal Lake Group (Unit 11).

Subunit 2c

Diffusely granitoid-layered tonalitic and granodioritic gneiss.

Distribution

Subunit 2c only occurs in the east half of NTS map area 13L/6. Most outcrops are within 1 to 7 km east of Sail Lake, where the subunit is interlayered and infolded, in interference patterns, with supracrustal rocks of Unit 1. A subsidiary area of outcrops, also interlayered with Unit 1, is found 5 to 10 km southeast of Proof Lake.

Description

Subunit 2c consists mostly of cream- to buff-weathering, medium- to light-grey, fine-grained biotite granodiorite and biotite tonalite. The granoblastic quartz, feldspar and mica minerals are homogeneously distributed and the felsic minerals appear sugary textured. Biotite (locally chloritized) is the most abundant ferromagnesian mineral; magnetite is commonly present and hornblende and garnet are rare. The colour index ranges between 5 and 10.

The rocks are characterized by abundant but diffuse leucocratic segregations and related biotite schlieren (Plate 23). The segregations occur as centimetre- to metre-wide sheets, dykes and veins of various granitoid compositions that have indistinct or irregular margins and that are commonly discontinuous. Discordant veining is commonly more prevalent than gneissosity, and, locally, veins are related to structures such as shear zones and fold axial planes (Plate 23). Most veining is folded, commonly together with the gneissic foliation and the biotite schlieren. Rarely, garnet overgrows the biotite schlieren. Typically, the gneissosity is undulating or wavy. Quartz veins add to the complexity of the veining but there are also some massive, more homogeneous layers. Zones containing weakly developed mylonitic fabrics are characterized by irregular, flattened, porphyroclastic feldspar and quartz ribbons. These are not as common as in the tonalitic and granodioritic orthogneisses (subunits 2a and 2b).

Plate 23. *Diffusely felsic-layered granitoid gneiss (subunit 2c) containing concordant and discordant felsic veins, the latter, in part, occurring along low-angle shear zones, which have an overthrust sense of movement. Photo GN81-CP40-13, locality G773, NTS 13L/6E, GR 8935.2789. Length of hammer is 34 cm.*

Locally, phases of slightly different composition are present and, rarely, the felsic minerals have medium grain size. Relicts of originally coarser grains in the form of 2 to 5 mm quartzofeldspathic shape aggregates are also rare, but form transitional facies into tonalitic gneiss of subunit 2a.

Inclusions of earlier light- to dark-grey dioritic to tonalitic phases of Unit 2 are scattered throughout, as are enclaves of amphibolite. Paragneiss and possible Orma dyke tonalite xenoliths occur locally. Subunit 2c occurs as enclaves in foliated tonalite (subunit 2d) at a locality adjacent to the road north of Proof Lake, and in association with other leucosome development, is diffusely veined by similar tonalite northwest of Proof Lake.

Petrography

The primary assemblage consists of plagioclase > quartz ± microcline + biotite + opaque mineral ± hornblende with zircon + monazite ± apatite as the accessory minerals. Biotite is brown, commonly forms discontinuous selvages to felsic location fabrics, and mostly exhibits a good mineral fabric. Locally, however, some biotite statically overprints the foliation. The felsic minerals range from polygonal to anhedral and from equant to elongate in a direction parallel to the foliation.

A volumetrically minor retrograde assemblage of epidote, chlorite, muscovite and saussuritized plagioclase occurs throughout subunit 2c; carbonate occurs locally with some biotite-rich seams. Chlorite commonly replaces biotite along its cleavage, muscovite is random, and muscovite (locally with chlorite) occurs as coarse-grained recrystallization products of saussuritized feldspar.

Structure and Metamorphism

Diffuse leucocratic segregations are the dominant feature of the rock (Plate 23). Some are parallel or subparallel to the mineral and shape-aggregate foliations, helping to both enhance and define the main foliation; some are discordant. Biotite schlieren and flattened inclusions also commonly enhance the main foliation, and the weakly mylonitic layers appear to be a zonal intensification of this fabric rather than a crosscutting event.

Many of the leucocratic segregations, both concordant and discordant, are earlier than the main foliation, as are quartz veins that are folded and foliated by the main foliation-forming event. Amphibolite enclaves, containing stromatic to venitic felsic veins that appear to be truncated by the enclosing gneiss, may contain remnants of even earlier migmatite fabrics.

Many minerals have been statically recrystallized after the main foliation development. Felsic minerals are commonly polygonal and sugary textured, biotite preserves the foliation, probably mimetically, and garnet overgrows biotite schlieren. The last feature is restricted to the aggregate pit northeast of the major bend in the road between Proof and Sho lakes. Retrograde chlorite is also present.

The veining and main foliation are moderately to tightly folded, and also exhibit open undulations and warping, which generate a characteristic wavy pattern in some outcrops. The open folding is commonly associated with groups of small shears that exhibit a consistent displacement sense, and along which leucosome veins are locally developed. Late quartz veins cut these structures.

Contact Relationships

Transitional relationships are indicated with tonalite gneiss (subunit 2a); foliated tonalite (subunit 2d) and mafic dykes (subunit 2f) intrude subunit 2c; no relationship is evident with subunit 2b granodiorite gneiss or subunit 2e granite. Subunit 2c contains abundant amphibolite enclaves of subunit 1a and rarer inclusions of metagabbro (subunit 1b) and tonalite to diorite (possibly subunit 2a). Many amphibolite inclusions are net-veined, rarely by the orthogneiss and more commonly by felsic material, which may be distinct from, or similar to, the granitoid sheets and veins in subunit 2c orthogneiss. The orthogneiss and paragneiss (subunit 1e) are interlayered over several tens of metres in a zone at the contact between the two subunits 3.5 km northeast of Sail Lake. Seven kilometres east-southeast of Sail Lake, zones of paragneiss inclusions (subunit 1e) occur in the orthogneiss adjacent to, and in the vicinity of, a paragneiss layer.

Subunit 2c is intruded by granitic dykes (subunit 3c), and is in fault contact with the Seal Lake Group (Unit 11) to the east.

Subunit 2d

Foliated quartz diorite and tonalite.

Distribution

The subunit forms six occurrences scattered throughout the northeast corner of the map area (Map 93-19). Occurrences range from veining within an outcrop to clusters of outcrops up to 2 by 1 km. The largest body is just east of Duck Bay and is elongated in a northerly direction adjacent to the supracrustal rocks (Unit 1). Several outcrop ridges define a 1 km^2 area, 7 km east of Sail Lake. Two outcrops occur by the roadside 2 km north of Duck Bay, and several outcrops occur along or near the road between Proof Lake and the major bend in the road halfway to Sho Lake. The subunit is present as dykes and net-veins in metagabbro (subunit 1b) 5 km northwest of Duck Bay and as leucocratic veins in orthogneiss (subunit 2c) 2 km northwest of Proof Lake.

Description

Subunit 2d, in the area east of Duck Bay, consists of a massive, grey, fine- to medium-grained, black-spotted, plagioclase-porphyritic quartz diorite to tonalite. The distinctive black spots are hornblende laths and biotite clots up to 4 mm across, giving a colour index of 10 to 15; plagioclase phenocrysts are 2 to 4 mm across, equant, euhedral to subhedral, and commonly saussuritized. Quartz content ranges from 5 to 35 percent. The rock is moderately to well foliated, defined by an anastomosing or penetrative mineral fabric and a biotite-clot shape fabric. Minor leucocratic layers, marked only by a reduced to absent ferromagnesian content, parallel the foliation, as do rare, long, thin, amphibolitic or biotite-rich schlieren. Discordant quartz and felsic veins are also rare.

The outcrop ridges 7 km east of Sail Lake are homogeneous; black, ferromagnesian spots are evenly distributed within a white felsic groundmass. Two kilometres north of Duck Bay, the spotting consists of black biotite clots that define most of the colour index of 5 to 10, and the quartz content exceeds 30 percent; this occurrence is well foliated.

Along the road north of Proof Lake, the outcrops are composed of either fine- to medium-grained biotite–hornblende-quartz diorite or hornblende–biotite-quartz diorite. In the hornblende–biotite-quartz diorite, the biotite forms random, 1 to 2 mm spots and the hornblende occurs in the groundmass where it is moulded around plagioclase. Locally, the rock contains enclaves of light-green leucoamphibolite (possibly subunit 1a or 1b) or grey orthogneiss (subunit 2c).

Where the subunit occurs as tonalite veining in subunit 2c northwest of Proof Lake, the veining is parallel to or associated with other discordant leucocratic veins in the orthogneiss.

Northwest of Duck Bay, the rock is a fine-grained, sugary-textured biotite tonalite. The granular plagioclase–quartz matrix (0.5 mm grain size) contains 1 to 5 mm black clots of biotite and rare, 3-mm-across, rounded, dark-grey plagioclase relicts. The biotite occurs as dense to diffuse clots of individual grains (0.5 mm across) that are commonly flattened in the foliation. The colour index is normally 10 to 15. Locally, millimetre-thick concentrations of the ferromagnesian minerals and millimetre- to centimetre-scale leucocratic bands define a diffuse layering.

Petrography

Modally, subunit 2d is comprised of tonalite, quartz diorite and, very rarely, granodiorite. Biotite is dark brown to olive green and occurs in the clots with opaque grains ± titanite. The biotite clots have been elongated or flattened in the foliation, but the mineral fabric internal to the clots is either foliated, mimetic or isotropic, and the biotite commonly exhibits subgrains or is recrystallized.

North of Duck Bay, titanite occurs in subunit 2d as large (up to 0.8 by 3 mm), lamellar-twinned, sphenoidal grains. It also forms small to medium anhedral grains that commonly exhibit core-overgrowth relationships and are associated with opaque minerals. Zircon, apatite and possible monazite are the accessory phases in the subunit. The retrograde assemblage consists of an epidote alteration of plagioclase, replacement of biotite (chlorite and a colourless, fibrous mineral) and coarse-grained muscovite recrystallization of saussuritized plagioclase.

Most felsic minerals are anhedral to polygonal. In the well-foliated rock north of Duck Bay, coarse-grained, anhedral, strongly sutured feldspar aggregates and polygonal quartz aggregates are partially enclosed in a weak mortar texture of fine-grained, polygonal felsic minerals.

Structure and Metamorphism

The prominent structure in the subunit is the ferromagnesian fabric, defined by the black clots, laths and elongate spotting, and the less obvious quartzofeldspathic mineral and aggregate fabric that occurs in the groundmass. This foliation is enhanced by leucocratic layering and by schlieric biotite-rich or amphibolitic strips.

Locally, the layering predates the foliation, e.g., northwest of Duck Bay, and the ferromagnesian schlieren are probably earlier too. (The biotite-rich seams may be restite equivalents of the leucocratic layering, whereas the amphibolitic strips could be screens of subunits 1a and 1b or thin mafic dykes (subunit 2f).) An even earlier structure is represented by the gneissosity in the orthogneiss enclaves of subunit 2c; no earlier structures were seen in the leucoamphibolite enclaves.

The biotite clots form either flattened shape aggregates within the foliation or equant clots growing across it that represent post-foliation static crystallization. Sugary textures in the felsic groundmass may also reflect static crystallization.

Contact Relationships

East of Duck Bay, quartz diorite dykes of subunit 2d intrude amphibolite (subunit 1a); northwest of Duck Bay, tonalite net-veins laminated gabbro (subunit 1b); and elsewhere, inclusions of amphibolite (possibly subunit 1a or 1b) occur in the subunit. Subunit 2d also intrudes or 'sweats out of' subunit 2c north and northwest of Proof Lake. North of Duck Bay, the granodiorite to tonalite is intruded by granite (subunit 3c) dykes.

Subunit 2e

Foliated, only locally migmatitic, commonly K-feldspar-megacrystic monzogranite and granite, and minor quartz monzonite.

Distribution

The largest outcrop area of this subunit forms a blunt crescent-shaped area, about 5 km long and concave toward the north-northeast, in the southwestern corner of the Unit 2 outcrop area. A similarly sized area, but only exposed in lakeshore outcrops, occurs between Vollant and Kasheshibaw lakes as an equant area, 6 km across, that has an easterly oriented, 2-km-long prong extending from its southeastern corner (Map 93-19). The subunit underlies a prominent monadnock near the northern margin of the map area about 9 km north-northwest of Sail Lake. Two kilometres to the south-southwest, and separated from the first monadnock by a saddle, a second monadnock is unexposed but is assumed to be underlain by the same rock type. The surrounding drift-covered plateau, however, is presumed to be underlain by orthogneiss (subunits 2a and 2b). These hills form a north-northeast-trending, approximately 5 by 1.5 km ridge. In the centre of Kasheshibaw Lake, a 1-km-across group of islands is also underlain by subunit 2e, as is an easterly trending, 0.3 by 1 km area at the northeast corner of Rusty Island in Fraser Lake. Nine kilometres east of the east end of Mackenzie Lake, a small (1 km^2) area of outcrops is included here with subunit 2e, but may be a granite belonging to subunit 3c. Subunit 2e is common as scattered outcrops and as sheets and dykes in earlier phases of Unit 2 to the north of Fraser Lake and in western areas of Kasheshibaw Lake.

Description

The largest outcrop area is underlain by a relatively homogeneous body of massive, fine- to medium-grained, rarely K-feldspar-porphyritic, foliated biotite granite. K-feldspar varies in proportion from 1:1 to 3:1 relative to both plagioclase and quartz. The colour index ranges from 2 to 10, and muscovite occurs locally throughout the body. The rock is pinkish-weathering with rare brown-weathering zones; in its westernmost outcrops, a brown spotting may signify the presence of orthopyroxene.

The granite has a granoblastic groundmass. Locally, small, relict, primary K-feldspar is present. A weak to strong foliation, with a variably developed linear component, is common. The foliation is defined by the following features: a biotite mineral fabric and rare foliae; K-feldspar orientation; aggregates of quartz or feldspar and rare quartz ribbons in coarser grained areas of the protolith; and scattered quartz and granitic veins that, locally, are tightly folded.

Between Vollant and Kasheshibaw lakes, the subunit consists of K-feldspar-megacrystic, biotite-quartz monzonite and monzogranite. Where only moderately foliated, these rocks contain inclusions of granodiorite (subunit 2b) and amphibolite (subunits 1a and 1b), are intruded by mafic dykes (subunit 2f), and contain relicts of primary K-feldspar, up to 5 cm across. However, in most places the rocks are strongly deformed, and on the north shore of Vollant Lake, they range from porphyroclastic augen gneiss through mylonite to ultramylonite. In the augen gneiss, relict K-feldspar is less common, recrystallized quartz and feldspar aggregates are normal, and a biotite foliation anastomoses around both features. With increasing deformation the following variations occur: i), relict megacrysts are smaller and very rare; ii), aggregates are thin, stretched and ribbon shaped; iii), muscovite occurs in places; iv), quartz has segregated into, mostly concordant, veins; and v), the rock is banded white, orange, grey and pink. The zones of greatest deformation contain no relict feldspar, have increased amounts of fine to very fine grained layering that is moderately to tightly asymmetrically folded, exhibit increased discordance of quartz veining and granitoid segregations, and have layered sheets of glassy ultramylonite cutting through the folds. These zones are openly folded. Commonly, biotite is chloritized throughout this area.

The area north of Sail Lake was originally a homogeneous, K-feldspar-megacrystic, medium- to coarse-grained monzogranite. The monzogranite is massive, pinkish weathering, and on fresh surfaces is grey and spotted with pink feldspar.

The megacrysts form mainly unrecrystallized, porphyroclastic augen up to 2 cm across. Locally, a pinkish colouration occurs at feldspar rims (possible rapakivi texture) and as blobs throughout the megacrysts (possible recrystallized subgrains or perthitic inclusions). The megacrysts have round cross-sections normal to the lineation, and subhedral or oval to lenticular, necked or fractured forms (with or without recrystallized tails) parallel to the lineation. Some of the fractures are filled by quartz. Rare porphyritic plagioclase is much smaller than the K-feldspar phenocrysts.

The groundmass consists of recrystallized shape aggregates of quartz, quartz + biotite, plagioclase and an opaque mineral. Quartz ribbons, along with the relict-megacryst orientation, define a moderate to strong, locally platey, foliation. The foliation is paralleled, locally, by folded and recrystallized quartz veins.

The islands in Kasheshibaw Lake consist of buff-weathering, massive, inhomogeneous outcrops of grey, coarse-grained, K-feldspar-megacrystic biotite monzogranite to quartz monzonite (e.g., Plate 24). Quartz, plagioclase, biotite, magnetite and allanite form the groundmass around the K-feldspar megacrysts. The largely rectangular (up to 3 by 1.5 cm) porphyroclastic megacrysts exhibit rounding and variably recrystallized margins. All mineral elements contribute to the strong foliation; quartz and feldspar form polycrystalline-groundmass shape aggregates and biotite occurs as anastomosing foliae. A lineation is weakly developed.

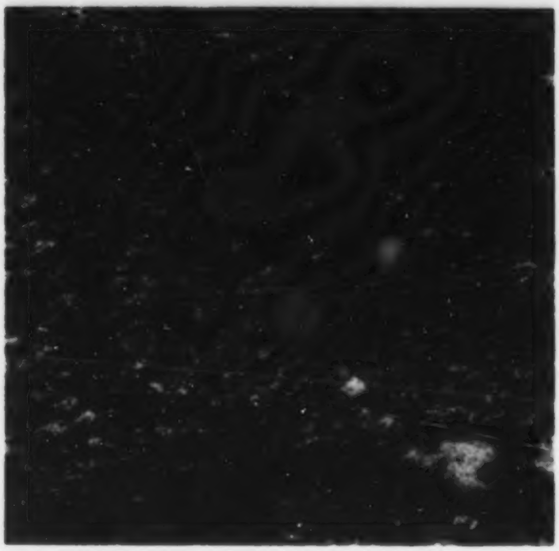


Plate 24. *Augen-textured, K-feldspar-megacrystic biotite monzogranite (subunit 2e). Photo and locality NN81-341, NTS 13L/5E, GR 6381.1850. Diameter of lens cap is 5.5 cm.*

Darker coloured, finer grained inclusions, layers and shear zones containing lower concentrations of smaller, more strongly porphyroclastic feldspar are present in some outcrops. Rare, small xenoliths of either pink granite or dark rock, together with 1- to 3-mm-wide dark strips and 1- to

5-cm-wide K-feldspar-free (tonalitic) layers parallel to the foliation, add to the inhomogeneity. Rare, fibrous-structured quartz veins also occur.

On Rusty Island, the subunit forms massive cream- to grey-weathering outcrops of grey monzogranite. Mostly the monzogranite is equigranular, homogeneous and composed of recrystallized aggregates; locally, it contains a weak foliation and felsic-vein layering.

In the southeast of the map area (Map 93-19), subunit 2e/3c is massive, red to pink, and was formerly a K-feldspar-porphyritic, medium- to coarse-grained, quartz-rich granite. Porphyritic K-feldspar is now represented by oval shape aggregates. Groundmass minerals and aggregates are polygonally recrystallized and consist of fine-grained feldspars and coarser-grained quartz. Greenish streaks are also present. The moderate to strong foliation is enhanced by polygonally textured granitic segregations and quartz veins containing minor intergranular K-feldspar; in places, both features are irregular and folded. The granite also contains fine grained zones and, locally, arkosic metasedimentary enclaves.

Petrography

The K-feldspar megacrysts consist of orthoclase microperthite that is partly or totally inverted to microcline. Forms with single twins are common. Subgrains and patches of granular recrystallization and discontinuous marginal recrystallization (ranging to anhedral aggregates) are abundant, but complete recrystallization is rare. Small, euhedral plagioclase and biotite inclusions may be primary, but scattered inclusions of muscovite, chlorite and polygonal quartz are probably secondary. In the Kasheshibaw Lake outcrops, the megacrysts are corroded by myrmekite.

Two types of fractures affecting the megacrysts have been recognized in thin section. In Kasheshibaw Lake, length-oblique fractures are characterized by granulation of the feldspar, with or without the crystallization of quartz, biotite and muscovite. North of Sail Lake, the fractures are more or less orthogonal and contain quartz ± epidote ± chlorite.

The groundmass of the megacrysts is composed of quartz, mostly as ribbons, plagioclase and biotite and minor microcline. The biotite is brown or brown to olive green and commonly associated with opaque minerals ± titanite. Titanite ± opaque-mineral intergrowths or rims are abundant in the Kasheshibaw Lake outcrops; allanite, apatite and zircon are common accessory minerals. Biotite, opaque minerals, titanite and the felsic minerals in the groundmass crystallized during development of the foliation, and, north of Sail Lake, epidote is also a stable constituent of the foliation-forming assemblage. Muscovite poikiloblastically overprints the foliation; locally, chlorite has replaced biotite.

Outcrops of subunit 2e/3c south of Marie Lake, contain a complex deformation history of recrystallization, grain-size reduction, foliation development and crenulation. The green streaks consist of chlorite and opaque minerals and define a colour index of 5 to 8. Rare, ragged biotite relicts occur in the cores of some chlorite patches.

Structure and Metamorphism

All parts of subunit 2e are moderately to strongly foliated; platy, mylonitic zones occur in the outcrops north of Sail Lake, and augen gneiss and mylonite are common at Vollant Lake. The foliation is the main deformation structure and it is defined by: 1), flattening and rotation of K-feldspar megacrysts; 2), quartz, plagioclase and K-feldspar shape fabrics (including quartz ribbons); 3), biotite mineral fabric and foliae; 4), mimetic allanite; and 5), migmatitic location fabrics, mylonitization and concordant quartz veins. Some of the location fabrics are isoclinally folded and others are transposed earlier structures; the main foliation is axial planar and subparallel, respectively, to these location fabrics. Recrystallization of the margins and generation of pull-apart structures in K-feldspar megacrysts occurred during the main deformation. Subgrain recrystallization within the megacrysts probably occurred at the same time or during posttectonic annealing.

Recrystallization outlasted formation of the main foliation in many rocks, as demonstrated by the polygonal nature of some quartzofeldspathic aggregates and mimetic allanite and biotite growth. Continuing leucosome generation is indicated by discordant veining. Later structures are also represented by folding of the foliations and veins, ultramylonite sheets, and further folding. Folding occurred without new fabric development. Mimetic and random replacement of biotite by chlorite represents later retrogression, and brown spotting in the west is probably a thermal effect resulting from the emplacement of the Michikamau Intrusion (Unit 10). Other late structures consist of the fibrous discordant quartz veins.

Contact Relationships

Sheets of pink monzogranite (subunit 2e) occur interleaved with migmatitic granodioritic gneiss (subunit 2b) to the east and northeast of subunit 2e at the west end of Kasheshibaw Lake, and inclusions of granodiorite gneiss (subunit 2b) occur in monzogranite and quartz monzonite in western areas of the lake. The monadnocks in the north of the map area are surrounded by unexposed, drift-covered peneplain and most other outcrops are surrounded either by drift or by water. The subunit contains mafic dykes (subunit 2f) and has probably been thermally metamorphosed by the Michikamau Intrusion (Unit 10) in its western localities. The granite in the southeast of the map area contains enclaves of arkosic metasedimentary rock (Unit 4) and is in fault contact to the east with the Seal Lake Group (Unit 11).

Subunit 2f

> *Pretectonic mafic, intermediate, felsic, amphibolite, hornblendite and metadiabase dykes.*

Distribution

Subunit 2f occurs throughout the outcrop area of the supracrustal rocks (Unit 1) and the Sail Lake intrusive suite (Unit 2) at outcrop scale. It has not been possible to record all the localities on the map, and only the larger occurrences are shown (Map 93-19). These are mostly in the southeast of the map area and in north-central areas in and around the reservoir.

Description

The subunit comprises several sets of dykes, which differ in both composition and age. Mafic and felsic, and possibly rare intermediate and ultramafic (now hornblendite) dykes intrude Unit 1 (Plates 25 and 26). They are, in part, probably related to the supracrustal sequence as feeders to the mafic extrusive (subunit 1a), hypabyssal (subunit 1b) and tuffaceous (subunit 1d) members of the succession, and these, therefore, are entirely pretectonic. Other mafic dykes intrude the various phases of the plutonic orthogneiss suite (Unit 2) and contain fabric elements and leucosomes typical of Unit 2 (e.g., Plate 27); they are, therefore, broadly synplutonic relative to emplacement of the orthogneiss protolith and pre- to syntectonic relative to the deformation producing the

Plate 25. *Massive amphibolite (metagabbro, subunit 1b) intruded by necked and boudined mafic dyke (subunit 2f). The metagabbro appears mottled, the dyke contains the hackly fracturing. Photo GN81-CS26-26, locality G531, NTS 13L/3W, GR 8350.9895. Length of hammer is 34 cm.*

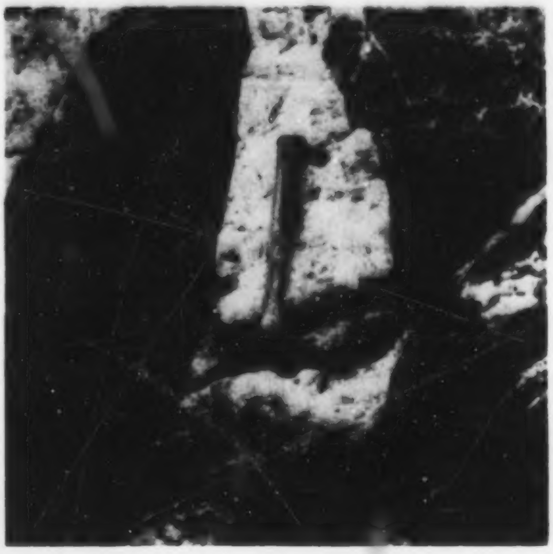


Plate 26. *Banded amphibolite (subunit 1a, bottom right) and massive metagabbro (subunit 1b, top right) intruded by felsic dyke (subunit 2f), with folded apophyses, cored by multiple hornblendite dyke (also subunit 2f). The second hornblendite dyke intruded up the centre of the earlier one and is about 18 cm wide. Note the steep lineation in the banded amphibolite. Photo GN80-CS19-3, locality G449a, NTS 13L/3E, GR 9105.9186. Length of hammer is 34 cm.*

Plate 27. *Migmatized mafic dyke (subunit 2f), foliated and infolded with Orma dyke tonalite (subunit 2a). Photo GN80-CS20-35, locality G443b, NTS 13L/3E, GR 8905.9686. Length of clinometer is 10 cm.*

orthogneiss. Some of the dykes intruding the supracrustal rocks are probably coeval with this later episode. A third set of mafic dykes intrudes both Unit 1 and Unit 2, generally crosscuts foliations or fabrics in these units, is less intensively deformed than its hosts and is not migmatitic (e.g., Plate 2), i.e., it is late tectonic with respect to the deformation affecting Units 1 and 2. Minor intrusions related to Unit 2, e.g., the pink granite dykes (subunit 2g) and the numerous felsic vein generations, are excluded from these dyke sets.

Most dykes are less than 1 m thick. Of the three sets of dykes noted above, the first is the most common and locally forms up to 10 percent of the sequence, e.g., five dykes make up 1.66 m of the southern half of the approximately 29-m measured section in the east of Fremont Lake (Figure 10 and Table 1). The other two dyke sets are sporadic. Dyke orientations are very variable.

Felsic dykes are granoblastic and feldspar aggregates indicate that some are plagioclase porphyritic. They are fine to medium grained and white or cream weathering (e.g., Plate 26).

Mafic dykes are recrystallized to amphibolite or to a plagioclase–biotite rock. The amphibolite dykes are usually black and fine to medium grained, the plagioclase–biotite dykes are dark grey and fine grained. Mafic dykes range from homogeneous to relict porphyritic and/or ophitic in texture; phenocrysts have been pseudomorphed by hornblende and plagioclase. Other relict primary structures include chilled margins, apophyses, xenoliths, step structures and back-veining. Secondary features or processes include porphyroblastesis, recrystallization, necking, boudinage, brittle pull-aparts and fractures, veining, net-veining, migmatization, folding and foliation. Foliations range from weak to strong, commonly mirror the rodding or other fabrics in their host, and, rarely, include stromatic felsic veining, as well as the more common discordant veins. Locally, foliations in the dykes are internally folded or folded with the dykes. Minor epidotization is ubiquitous.

Dykes of amphibolite range from leucocratic (colour index less than 15) to ultramafic (colour index greater than 90). Rarely, dykes are colour banded or layered. At a locality between Fremont and Mackenzie lakes, there is a composite dyke (Plate 26). The felsic outer part of the dyke cuts the layering in the adjacent amphibolite (subunit 1a) and the contact between this amphibolite and metagabbro (subunit 1b): it is cored by a hornblendite dyke, which is itself multiple and contains internal chilled contacts.

Petrography

Mafic dykes intruding the layered amphibolite in the quarry southeast of Sail Lake contain the assemblage plagioclase–hypersthene–green hornblende–red-brown biotite–clinopyroxene–opaque mineral–colourless amphibole. Oval patches, 4 to 6 mm long, of anhedral to polygonal granoblastic plagioclase represent recrystallized porphyritic grains. The groundmass consists of finer grained (up to 0.5 mm), granular, polygonal plagioclase and opaque minerals, internally containing scattered, very fine grained, polygonal spotting and exhibiting lobate grain-boundary migration. In the groundmass, the generally evenly distributed ferromagnesian minerals are moulded on the plagioclase and define a colour index of about 40. The ferromagnesian minerals consist of equigranular anhedral hornblende of similar size to the plagioclase, and very heavily sieved poikiloblastic hypersthene up to 8 mm across; these define a weak location or shape fabric that parallels a weak mineral fabric in the plagioclase. The orthopyroxene poikiloblasts commonly have a 0.5- to 1-mm-wide felsic halo around them, and where these are discontinuous, the hypersthene is buffered by colourless amphibole against hornblende. For up to 0.5 cm adjacent to feldspathic leucosomes in the dyke, hypersthene is much less common and poikiloblastic biotite, up to 3 mm across, and clinopyroxene, armoured by colourless amphibole, occur in association with the hornblende. Within the feldspathic sweat, both pyroxenes are present and both are rimmed by colourless amphibole, and, together with plates of red-brown biotite and minor opaque minerals and green hornblende, they define the colour index of 20 to 25.

The assemblages in the dyke and its migmatitic leucosomes probably relate to peak-metamorphic dehydration reactions (see discussion of posttectonic recrystallization in the later part of Archean structures in the Depositional and Tectonic History chapter).

Structure and Metamorphism

All dykes in subunit 2f are deformed. Their main structure is usually a foliation defined by mineral or shape fabrics. These include plagioclase and hornblende groundmass mineral fabrics, biotite foliations, lineated hornblende porphyroblasts, and flattened intergranular to ophitic textures. Locally, the foliation is enhanced by discontinuous or stromatic leucosomes and by zones of more intense shearing. These structures developed in the amphibolite facies. Late members of the suite crosscut features (e.g., leucocratic segregations and strong fabrics) in their host but commonly still contain similar structural orientations and fabric elements (e.g., steep lineations) to these rocks, albeit less intensely developed.

Folds of veins, to which the main foliation is axial planar, indicate earlier development of migmatitic and net-veins. Folding of the foliation, development of crosscutting veins and fractures, migmatization, replacement of main-foliation fabric elements by granoblastic recrystallization, and crystallization of posttectonic porphyroblasts may have occurred soon after foliation formation and, at least locally, are associated with peak metamorphic conditions. Development of crosscutting veins and fractures continued into, or recurred in, the greenschist facies (epidotization).

Contact Relationships

Subunit 2f intrudes most subunits of the supracrustal rocks (Unit 1) and the Sail Lake intrusive suite (Unit 2), including the granitic dykes described below (subunit 2g).

In places, however, the subunit is also intruded by most of the subunits of Unit 2, due to the range in time of emplacement of the dykes.

Subunit 2g

Syntectonic granitic sheets, dykes and veins.

Distribution

Subunit 2g occurs scattered throughout the supracrustal rocks of Unit 1 and in many outcrops of the Sail Lake intrusive suite (Unit 2); however, it is delineated on the map in only those cases where the subunit constitutes the whole outcrop. Mostly, these occur south of Fremont Lake among the supracrustal rocks.

Description

The subunit consists of a suite of granitic (invariably alaskitic) sheets, dykes and veins. These are ubiquitous throughout Units 1 and 2, but vary from rare to common in any one group of outcrops. Although generally centimetre- to metre-scale in width, they range up to a decametre or more across. Mineralogical compositions of monzogranite, granite, alkali-feldspar granite and quartz-rich granitoid rocks occur. Commonly, only one feldspar is discernible and the colour index is defined by traces of magnetite and up to 5 percent biotite; muscovite is rare. The subunit is fine to coarse (pegmatitic) grained and weathers pink, buff, white or grey; the overall colour on fresh surfaces is grey or pink. Quartz-rich parts of the rock are grey, white or bluish grey.

Texturally, the less deformed rocks are pegmatitic, granitic, aplitic, graphic, porphyritic, equigranular and seriate, commonly in combinations of two or more of these within the same dyke. Pegmatitic varieties locally contain peg-structured feldspar and are commonly quartz cored. Porphyritic rocks range up to megacrystic and contain large K-feldspar and/or plagioclase, and megacrysts of the former commonly are clearly perthitic; quartz is intergranular to euhedral and subhedral feldspar.

The suite is discordant and emplaced into brittle fractures of tensile, net-vein and, rarely, shear type. The rocks are generally massive but range from undeformed to strongly foliated and locally mylonitic. Internal-deformation structures consist of foliations defined by shape aggregates of recrystallized felsic minerals, and are commonly zonal and related to such things as the orientation of the structure (i.e., dyke-parallel), grain size, and fold limbs and axial zones; one sheet of constant across-width grain size was observed to have a strong linear fabric along its margins and a weak planar fabric in its core. Dykes range from straight through wavy to folded, and from rectiplanar to feathered, or through necked to disrupted. The larger sheets and dykes commonly give elevated scintillometer readings of 1000 to 3000 total cps, some forty times the normal readings for the orthogneiss suite (Unit 2).

Petrography

Recrystallization of the quartzofeldspathic minerals has resulted in anhedral to polygonal blastic textures. Anhedral textures are dominated by interlocking allotriomorphic grains, commonly with lobate grain boundaries. Curved grain boundaries are more abundant than straight ones in polygonal textures; quartz commonly is saccharoidal. Felsic minerals exhibit a weak fabric. Porphyritic feldspar commonly is partly recrystallized and microcline is corroded by myrmekite.

The ferromagnesian and accessory mineral assemblage consists of some or all of biotite, epidote, titanite, opaque minerals, chlorite, apatite, allanite, hematite and zircon. Biotite, titanite, opaque minerals and allanite define a moderately well developed mineral fabric. Some zircon and titanite grains exhibit core-overgrowth relationships.

Structure and Metamorphism

Due to the heterogeneous effect of strain on this suite of dykes, the main structure is either the foliation or folds, commonly accompanied by feathered vein margins, necking and boudinage. In part, the two are coeval and commonly occur together. The foliation consists of a weak felsic mineral fabric and a moderate to strong biotite mineral fabric and felsic shape fabric. Titanite, opaque minerals and allanite also are aligned. The recrystallization took place at biotite grade in the amphibolite facies and is defined by the assemblage quartz–two feldspars–green biotite–titanite–opaque mineral ± allanite. The rocks are not migmatitic. Folding and foliation are commonly less tight and less intense, respectively, than in the adjacent host rock, but of the same orientation.

There are no earlier structures. Later structures consist of rare folding of the foliation. Epidote and chlorite are retrogressive.

Contact Relationships

The subunit 2g suite of granitic sheets, dykes and veins intrudes all of the rock types in Units 1 and 2. Though not necessarily common everywhere, the suite is ubiquitous throughout the Orma Domain (Units 1 and 2).

PROTEROZOIC I OR OLDER

Plutonic Suite (Unit 3)

Massive to foliated gabbro, diorite and alkali-feldspar-rich granitic rocks.

Definition and Division

Rocks defined in this report as Unit 3 were mapped by Emslie (1964b), who placed the basic rocks in a general group of 'anorthositic rocks' and included the granitoid rocks with a general group of 'massive granitic rocks'. Nunn and Noel (1982) equated the suite with the early gabbroic and later granitoid members of the Trans-Labrador batholith (North Pole Brook Intrusive Suite (Unit 9) and equivalents). Small differences in composition and major differences in tectonic and metamorphic features now require a designation that is earlier than the rocks of the Trans-Labrador batholith, which have not exceeded greenschist facies conditions since their initial cooling and which preserve mainly igneous-looking textures. In Unit 3, the dioritic rocks contain patches of incipient migmatite development, both the dioritic and granitic rocks are thoroughly recrystallized and metamorphic textured, and the granitic rocks lack titanite and are generally more quartz rich and more K-feldspar rich than the bulk of the Trans-Labrador batholith. As well, the strong, commonly linear, foliation anastomoses through the granitic rocks of the suite, in contrast to the more regularly oriented and planar foliation characteristics of the batholith.

Unit 3 is defined here as that suite of basic to acidic plutonic rocks that postdates the Sail Lake intrusive suite orthogneiss complex (Unit 2) but still contains indications of high-grade deformation and metamorphism. It is divided into three subunits on compositional grounds; broadly, gabbro, diorite and granitic rocks.

The gabbro–diorite–granite suite is mostly confined to the northeast part of the map area (NTS 13L/6E) where it forms an equant body about 12 km across between Sail Lake and Duck Bay, and a smaller 2 by 1 km body, 5 km east of the east end of Sail dyke, which is elongated in a north-northwesterly direction. Another small body occurs just north of the road between the main outcrop area and Duck Bay. Two islands define an equant 2.25 km^2 body in west-central Kasheshibaw Lake (southeast corner of NTS map area 13L/5E).

Age

The gabbro–diorite–granite suite is undated. However, it postdates the emplacement (and the major migmatitic events) of the Sail Lake intrusive suite (Unit 2). It appears to predate the ca. 1650 Ma Trans-Labrador batholith (North Pole Brook Intrusive Suite, Unit 9), which has not undergone such intense deformation and high-grade metamorphism. Thus, the unit is bracketed between the Late Archean (Unit 2) and the late Early Proterozoic (Unit 9).

Subunit 3a

Gabbro and hypersthene gabbro.

Distribution

Subunit 3a occurs as an approximately rectangular, 5 by 3 km body in the southwest of the main outcrop area, a northeasterly-trending, 3 by 0.5 km body along the southeastern margin of the main outcrop area, and forms the whole of the bodies 5 km east of Sail dyke and in west-central Kasheshibaw Lake.

Description

The larger, and western, of the two bodies near Duck Bay consists of dark-grey-weathering, dark-grey to white, fine- to medium-grained, commonly layered gabbro and hypersthene gabbro. The layering occurs on scales of centimetres to decimetres and is generally plane-sided but may be somewhat lenticular. Layers range in composition from anorthosite to melagabbro and locally contain rhythmic variation; these gabbros dip and young moderately to the east. Layered rocks are interspersed with thick, massive, homogeneous, dark-grey, equigranular gabbro. Detailed relationships between the homogeneous and layered gabbros are not known. Igneous textures are indistinct and the gabbroic rocks may, in part, be recrystallized.

The body farther east is a dark-grey, massive, medium-grained gabbro exhibiting an intergranular to subophitic texture of pyroxene and plagioclase. It is homogeneous and undeformed.

East of Sail dyke, the subunit consists of a massive, dark-grey melagabbro, characterized by centimetre-sized poikiloblasts of pyroxene or hornblende. The poikiloblasts enclose fine-grained, granular grains of plagioclase and pyroxene, and appear to have preserved a primary mineral assemblage.

In west-central Kasheshibaw Lake, two prominent islands are underlain by predominantly medium grained metaleucogabbro to metagabbro. A relict igneous texture is well preserved in places. The ferromagnesian minerals consist of hornblende, pyroxene, biotite and disseminated magnetite; the hornblende and pyroxene range from intersertal (leucogabbro) to intergranular (leucogabbro-gabbro) in texture. Most rocks are massive; finer grained varieties locally contain a weak, north-northeasterly trending foliation. Locally, fine-grained rocks form sheet-like bodies containing inclusions of medium-grained metagabbro, and the latter contains numerous ultramafic enclaves. At one locality, the metagabbro also contains enclaves of feldspar-porphyritic orthogneiss. Thin, undeformed, fine-grained diabase or dioritic dykes are common. Quartz veins and chlorite-mineralized fractures locally define tectonic fabrics.

Structure and Metamorphism

Homogeneous, equigranular mineralogy and a lack of igneous textures suggest some metamorphic recrystallization or an unusual primary-crystallization texture in the main body. Elsewhere in the east, the subunit appears unmetamorphosed; plagioclase and pyroxene, together with hornblende in the northern body, form the stable mineral assemblage. No tectonic structures were recorded except for rare plagioclase- or epidote-mineralized fractures and joints in these areas. Local zones of a weak foliation occur in the outcrops in west-central Kasheshibaw Lake but in general the metamorphic minerals pseudomorph igneous textures in this area. In Kasheshibaw Lake, fractures are mineralized with chlorite and quartz instead of epidote and plagioclase.

Contact Relationships

In Kasheshibaw Lake, the metagabbro contains cognate-looking inclusions and dykes(?), as well as enclaves of orthogneiss (Sail Lake intrusive suite, subunit 2b). Both bodies north of Duck Bay are cut by dykes of granite that are assumed to emanate from the local outcrops of granite (subunit 3c). No other contact relationships were observed.

Subunit 3b

Pyroxene, hornblende and biotite diorite.

Distribution

The diorite subunit is confined to the main outcrop area of Unit 3, where it occurs as a 25 km^2 subequant area of outcrop near the centre and as a north-south elongated 4 km^2 body on the eastern margin. In sharp contrast to the gabbroic rocks (subunit 3a) and the granitic rocks (subunit 3c), the diorites underlie the low ground.

Description

The subunit consists of dark-grey, light- to medium-grey-weathering hornblende–biotite–pyroxene diorite. The main rock is fine to medium grained, equigranular and thoroughly recrystallized, although locally, relict igneous textures, coarser grained to pegmatitic patches and porphyritic plagioclase are present (Plate 28). The rock comprises pyroxene, biotite and plagioclase porphyroblasts, aggregates of pyroxene and plagioclase, pegmatitic patches, irregular patches of biotite, leucocratic inclusions and coarser grained, leucocratic segregations. The colour index in the host rock ranges from 25 to 40, that in the leucocratic inclusions and segregations ranges from 10 to 20, and that in the pegmatitic patches ranges from 10 to 60.

Plate 28. *Heterogeneous metagabbro or diorite (subunit 3b). Darker and coarser patches are hornblende–plagioclase–biotite. Photo GN81-CP43-11, locality G779c, NTS 13L/6E, GR 8888.1697. Length of clinometer is 10 cm.*

The groundmass mineralogy exhibits a weak mineral fabric, and the leucocratic patches and rare, possibly cognate, inclusions show a similarly weak elongation and orientation. Aggregates of hornblende and plagioclase, however, commonly define a strong, steeply plunging lineation.

Petrography

The ferromagnesian assemblage consists of clinopyroxene–biotite–orthopyroxene–magnetite ± hornblende; euhedral epidote rims on orange-brown cores (probably allanite) are also present. The biotite is red-brown and the hornblende green. Plagioclase phenocrysts occur as rare relicts or as coarse polygonal aggregates. Granular, recrystallized, poikilitic clots of clinopyroxene and biotite probably represent recrystallization of former phenocryst phases.

Structure and Metamorphism

The groundmass minerals in the dioritic rocks range from an equant granoblastic texture to a weakly lineated mineral fabric. A crude orientation to the leucocratic segregations and the inclusions is parallel to the fabric and is generally steeply pitching. Hornblende porphyroblasts and shape aggregates of hornblende (possibly pseudomorphing pyroxene) and plagioclase commonly define a much stronger, steep lineation.

No structures earlier than this fabric have been recognized. Randomly oriented, possibly posttectonic, mineral crystallization variably affects the groundmass, the porphyroblasts and the leucocratic segregations.

Contact Relationships

The diorites may be the deformed and metamorphically recrystallized equivalent of the gabbroic rocks (subunit 3a); a field relationship was not seen. Abundant examples of an intrusive relationship between granite (subunit 3c) and the diorites are present. The diorites are intruded by dykes and veins of granite, which also contain diorite inclusions. The diorites contain layered amphibolite inclusions (subunit 1a) in outcrops 8 km south-southwest of Proof Lake.

Subunit 3c

Granite, monzogranite, alkali-feldspar granite,
quartz syenite, quartz monzonite and syenite.

Distribution

Subunit 3c forms several subrectangular to irregular outcrop areas, up to 20 km^2 in size, and a number of much smaller bodies chiefly within the main Unit 3 outcrop area north of Duck Bay. Small satellite bodies occur northeast and southeast of the main body.

Description

Granite, alkali-feldspar granite, quartz syenite, monzogranite, quartz monzonite and syenite (in approximately decreasing abundance) comprise this group of buff- to grey-weathering, red, fine- to coarse-grained alkali-feldspar-rich granitic rocks. They commonly display metamorphic-textured, fine- to medium-grained, granular mineral aggregates mixed with relict K-feldspar, quartz and plagioclase igneous mineralogy. However, large areas are undeformed. Up to centimetre-sized alkali-feldspar and smaller plagioclase phenocrysts are commonly embedded in anhedral, single or aggregate patches of quartz of similar size. Alkali feldspar is less commonly recrystallized than the other felsic minerals. The colour index ranges from 2 to 15 and the ferromagnesian minerals consist of hornblende, biotite and magnetite with rare garnet or allanite.

The quartz, K-feldspar and plagioclase aggregates define variably oblate to linear shapes. A weak to moderately strong foliation and lineation anastomose throughout the subunit.

Petrography

In the undeformed areas, the rocks exhibit an interlocking, anhedral, granitic texture. The alkali-feldspar granites contain a single feldspar exhibiting a wide range of perthitic structures and myrmekite-corroded patches. (In these rocks, plagioclase occurs only either as very rare, small, interstitial grains or as recrystallized perthite.) In less potash-rich rocks, the plagioclase is commonly porphyritic or occurs as smaller subhedral grains on which groundmass plates of quartz and K-feldspar are moulded. Ferromagnesian minerals occur in patches dominated by deep-green hornblende and dark-brown to red-brown biotite. Commonly, the darker hornblende contains pale greyish-green amphibole cores, or rims biotite–opaque mineral intergrowths. The cores of hornblende grains and aggregates are commonly more poikilitic than the rims, and enclose mixtures of biotite, epidote, quartz, opaque minerals, zircon, apatite and allanite.

Patches of fine-grained polygonal recrystallization, particularly at feldspar–feldspar boundaries, are common but not voluminous. Garnet apparently grew at the expense of biotite in a hornblende-free rock. Chlorite is rare and probably occurs as an alteration of hornblende and biotite.

Structure and Metamorphism

The felsic aggregates and biotite define the foliation. Recrystallization during fabric formation occurred at biotite grade. Garnet grew statically in an undeformed rock, either syn- or postkinematically.

No earlier structures are present. Later structures may consist of the wavy anastomosing patterns of the foliation, although this might be a primary feature. Other late structures are confined to random aplitic veins and chlorite- and epidote-mineralized joints and fractures; chlorite and epidote represent later retrogression.

Contact Relationships

The alkali-feldspar-rich granitic rocks form dykes and veins, and locally net-vein systems, within amphibolite (subunits 1a and 1b), pelitic paragneiss (subunit 1f), orthogneiss (subunit 2c), granodiorite to tonalite (subunit 2d), gabbro (subunit 3a) and diorite (subunit 3b). The small patch of subunit 3c, 4 km northwest of Desolation Lake, is either unconformable beneath red bed conglomerate and sandstone (Seal Lake Group, subdivision 11a^4) or in fault contact with it.

Metasedimentary Rocks of Uncertain Affinity (Unit 4)

Clastic metasedimentary rocks.

Definition and Division

Rocks defined here as Unit 4 were not known from previous mapping. Nunn and Noel (1982) included them with other 'red-bed' localities in their Proterozoic Mackenzie Lake group (Unit 8, this report). Red beds and associated volcanic rocks (Unit 8) at the west end of Mackenzie Lake are either in regional greenschist facies or contact metamorphosed at chlorite- to hornblende-hornfels grade, and contain little or no fabric. However, those at the eastern end of Mackenzie Lake are either at hornblende-hornfels grade or are in the amphibolite facies and locally migmatized, but also include chlorite-grade regional or thermal retrogression. The hornblende-hornfels grade rocks are similar in metamorphic state to those at the west end of Mackenzie Lake but the migmatized metasedimentary rocks are at much higher metamorphic grade.

These features point to an older age than the Mackenzie Lake group for the migmatitic rocks, and even suggest a correlation with supracrustal Unit 1. The unit is designated of uncertain affinity here because of potential problems with placing 'red-bed' sequences in the Archean (if the colouring is primary), because similar or other continental rock types are not known from the supracrustal succession, and because the age of migmatization might conceivably be younger than the Archean (see below).

Unit 4 is defined as those outcrops of locally migmatized, red-bed metasedimentary and associated (conglomerate, amphibolite and schist) rock types that cannot be confidently assigned to any of the sedimentary Units 1, 5, 8 and 11. The unit subdivisions are based respectively on psammitic, psephitic and pelitic metasedimentary facies.

Unit 4 occurs only in the southeast of the map area (southeastern quarter of NTS map area 13L/3E) where it underlies four, generally very small, areas of outcrop.

Age

The metasedimentary rocks predate a migmatitic event that must have occurred before the emplacement of the North Pole Brook Intrusive Suite granitoid rocks (Unit 9) at about 1650 Ma; regional metamorphism in the granitoid rocks does not exceed the greenschist facies. Migmatization and upper-amphibolite-facies metamorphism might have occurred in the Late Archean, during the Hudsonian Orogeny, early in the Labradorian Orogeny, or some intervening event. Geochronological isotope studies in the area (Nunn *et al.*, 1990) suggest that either the Late Archean or early Labradorian time are the most likely. Therefore the age is given as Proterozoic I or older.

Subunit 4a

Siltstone, sandstone and migmatized arkose.

Distribution

Subunit 4a occurs as three outcrop groups within the map area. The largest is a 2 km², northwest-elongated, ovoid patch 5 km south of Marie Lake. Outcrop pairs occur near the east end of Mackenzie Lake on the lakeshore, and in the Naskaupi River between Orma and Marie lakes, 5 km east of the Orma dyke.

Description

The largest outcrop area is composed of massive to bedded, salmon-pink-weathering, grey or reddish, fine- to medium-grained sandstone and arkose. Rare, 30- to 50-cm-thick, grey quartzitic (less feldspathic) layers occur within the red-bed succession, and an outcrop of amphibolite of unknown relationship is also present. Beds are tabular (exhibiting plane to slightly wavy surfaces), decimetre-scale in thickness, and internally homogeneous. Cross bedding gives tops to the east at two localities (one overturned); beds dip moderately to steeply to the east or west. The rocks contain a weak mineral fabric that is axial planar to thin, folded leucocratic veins. The fabric also varies in orientation through the outcrops. Some layers contain equant clots of randomly oriented chlorite up to 3 mm across.

Near the end of Mackenzie Lake, the outcrops consist of pale- to salmon-pink-weathering, grey, thinly bedded siltstone or arenite. In the Naskaupi River east of the Orma dyke, they comprise red-brown-weathering, thinly layered rock. At both locations the layering is generally 1 to 4 cm thick, plane-surfaced and internally parallel laminated, and the rocks are strongly recrystallized. Near the end of Mackenzie Lake, biotite-rich pelitic laminae and patches of pelite representing mudflake clasts occur locally within the sequence. Biotite also forms porphyroblastic clots up to 8 mm across. Rare leucocratic segregations contain both biotite and muscovite. The rocks are recrystallized and affected by small folds (which die out along strike within groups of beds) and kink bands. In the Naskaupi River, the layering and recrystallization relate to a very strong mylonite zone that strikes north-northwest across the river. The layering in the river outcrops also contains small asymmetric folds and kink bands.

Petrography

South of Marie Lake, subunit 4a consists of granoblastic-textured felsic rocks containing various mixtures of microcline, plagioclase and quartz. Locally, these rocks include abundant grains (similar in size to the felsic minerals) of a saussurite-like pseudomorph of an unknown mineral or grain (possibly originally detrital), minor amounts of an opaque mineral and rare tiny zircon. The arenite is very arkosic; microcline dominates and quartz is commonly subordinate to both of the feldspars and also to the pseudomorphs. Most grains are approximately equant and about 0.5 to 2 mm across. Very rare, subhedral, rectangular microcline, up to 2 by 4 mm across, is also present. Muscovite porphyroblasts occur as well as the chlorite clots in some rocks, and the fine-grained saussuritic pseudomorphs are partially recrystallized to coarser grained chlorite and muscovite, commonly along two or three intersecting directions.

The mylonitic rock in the Naskaupi River east of the Orma dyke consists of rare microcline, plagioclase, quartz and quartzofeldspathic porphyroclasts up to 3.5 mm long. The porphyroclasts have aspect ratios of 4 to 12:1 and are scattered in a granoblastic, polygonal, largely equant groundmass of quartz and feldspar and minor opaque mineral. The mylonitic foliation is defined by epidote- and/or chlorite-rich foliae; a carbonate ± chlorite ± quartz assemblage occupies tensional features in the rock. (These features are also consistent with mylonitization of a granitoid protolith such as subunit 9h microgranite (present only 2 km to the east), as well as of deformation of arenaceous metasedimentary rock.)

Structure and Metamorphism

In the outcrops to the south of Marie Lake, the arenite contains a thin, sparse, diffuse, migmatite location fabric. Folds of this leucosome contain a weak, axial-planar mineral fabric. East of Mackenzie Lake, quartzofeldspathic and mica mineral fabrics are strong and parallel to the layering, and are enhanced by a shape fabric to the biotite clots and pelitic clasts. The leucosome indicates regional metamorphism at upper amphibolite grade, and the pelitic clasts indicate posttectonic thermal metamorphism under conditions in which biotite is stable. In contrast, the recrystallization and flaggy structure in the river section occurred in the greenschist facies and are probably younger structures that are related to the mylonite zone.

The fabric is folded and the leucosome veins refolded at outcrop scale in the arenite south of Marie Lake, whereas smaller scale asymmetric folds of the lamination and/or flaggy structure occur at the other localities. In the Naskaupi River east of the Orma dyke, the folds are followed by kink banding.

Contact Relationships

The arenite is contact metamorphosed either by the adjacent monzogranite (subunit 2e/3c) or by close but unexposed rocks that might include tonalite (subunit 2a), monzogranite (subunit 2e/3c) or quartz monzonite (subunit 9d), which are all present in the local area. East of Orma dyke, the thinly layered rocks contain subconformable diabase dykes 5 to 40 cm wide (subunit 12a). Some dykes are altered and others are relatively fresh, indicating two generations of diabase intrusion. A greenschist-facies diabase dyke separates flaggy siltstone from the adjacent quartz monzonite (subunit 9d) to the east. Chloritization of the quartz monzonite, chlorite and epidote alteration of the diabase, refracted greenschist-facies foliations in different zones in the contact diabase, and parallelism of the most intense foliation in the diabase with the greenschist-facies laminations in the flaggy siltstone and the similar-facies mylonitic platiness in the granitoid rock (subunit 9d) to the west suggest that these contacts are tectonic or very strongly tectonically modified.

Subunit 4b

Quartzite-cobble conglomerate.

Distribution

The subunit occurs on the north side of the Naskaupi River, 5 km east of Orma dyke, as a 1 by 4-m-sized outcrop.

Description

The outcrop is composed of a grey-weathering, flattened, clast-supported, quartzite-cobble conglomerate (Plate 29). The cobbles consist of grey and white, fine-grained quartzite, and have dimensional ratios of approximately 3:1 or 4:1 in the plane of exposure. Small amounts of gritty and micaceous matrix occur between the flattened clasts.

Structure and Metamorphism

The main fabric is defined by the orientation of the flattened quartzite cobbles. It strikes in a north-northwesterly direction and dips steeply to the west-southwest. The matrix contains a grain-orientation fabric that is parallel to this plane, and both are equivalent structures to those in the mylonite in the granitoid rocks to the west (subunit 9d), and to the flaggy rocks (subunit 4a) and foliated diabase (subunit 12a) to the east. No earlier or later structures were noted in the conglomerate.

Contact Relationships

The conglomerate is thought to be in tectonic contact with subunit 4a across an approximately 4-m exposure gap to the east of the conglomerate. This may be a modified conformable or intrusive contact. Across a similar gap to the west of the conglomerate, subunit 4b is in structural juxtaposition with mylonitized granitoid rock of subunit 9d. A reverse sense of movement is inferred, such that the granitoid rocks are thrust up and over the metasedimentary rocks along a steeply pitching lineation.

Plate 29. *Deformed quartzite-cobble conglomerate (subunit 4b). Photo GN81-CS33-5, locality G604, NTS 13L/3E, GR 9420.9810. Length of hammer is 34 cm.*

Subunit 4c

Mica schist.

Distribution

The subunit is a single outcrop 1 km west of the post-reservoir affluence of the Naskaupi River into Marie Lake.

Description

The outcrop consists of a dark, fine-grained pelitic schist comprised mostly of quartz, feldspar and mica. The micas (dominantly biotite) exhibit a strong foliation and are chloritized.

Structure and Metamorphism

The schist is strongly foliated and consists of alternating foliae of quartz-rich and micaceous material. Chloritization of biotite represents post-biotite-grade retrogression.

Contact Relationships

The mica schist is an isolated outcrop.

Petscapiskau Group (Unit 5)

Pelitic, psammitic and psephitic metasedimentary rocks, mafic metavolcanic rocks, quartzite and minor metagabbro.

Definition and Division

Rocks defined here as Unit 5 were included in the metamorphic supracrustal sequences, described as 'metasedimentary rocks and derived schist and gneiss', that occur throughout the map area and form the oldest unit of Emslie's (1964b) original mapping. Subsequently, Emslie (1970) separated the unit from the remaining supracrustal rocks (e.g., Unit 1) in the map area by confining it to a discontinuous belt of hornfels and minor regionally metamorphosed rock close to the anorthositic Michikamau Intrusion (Unit 10) and named it the Petscapiskau Group after Petscapiskau Hill (near the west shore of Michikamau Lake, NTS map area 23I/8). The group was described as including paragneiss, schist, quartzite, metatuff and amphibolite, and their contact-metamorphosed equivalents; it was divided into 'paragneiss and schist' and 'metatuff and amphibolite' (Emslie, 1970). Nunn and Noel (1982) showed that the regionally metamorphosed rocks extended in a large lobe eastward from the southeastern corner of the Michikamau Intrusion, and returned the supracrustal rocks in the eastern part of the map area (Unit 1) to the group. In the same study (Nunn and Noel, *op. cit.*), much less deformed volcanic rocks near the southwestern corner of the map area were removed from the group and defined as a younger sequence (Unit 8).

Relationships between the Sail Lake intrusive suite (Unit 2) and the Petscapiskau Group (Unit 5) are equivocal. At one locality, sheets and dykes of tonalite (now gneiss) intrude pelitic metasedimentary rocks (now coarse grained, thermally metamorphosed paragneiss), suggesting a correlation between the Petscapiskau Group and the supracrustal rocks of Unit 1. However, the Petscapiskau Group everywhere appears to structurally overlie the orthogneiss unit and, outside of the paragneiss aureole, is at a considerably lower regional metamorphic grade than the orthogneiss (Unit 2), indicating a basement–cover relationship between the two. That the Petscapiskau Group comprises more than one supracrustal sequence, which might satisfy both of these conditions, is a possibility.

This uncertainty has led the author to confine the Petscapiskau Group, in this report, to the aureole around the Michikamau Intrusion, its regionally metamorphosed lobate extension, minor contact-metamorphic rocks on the southeastern side of this extension, and scattered isolated outcrops of unknown relationship to the orthogneisses (Unit 2) that occur close to the Michikamau Intrusion (Unit 10) in the western half of the map area. The Petscapiskau Group is thus defined as having an uncertain relationship to the Sail Lake intrusive suite (Unit 2), and hence also to the supracrustal rocks of Unit 1, and is separated from younger supracrustal rocks (Unit 8) on the basis of the presence of regional metamorphism and polyphase deformation that predate the thermal metamorphism induced by the North Pole Brook Intrusive Suite and the Michikamau Intrusion (Units 9 and 10, respectively). The Petscapiskau Group is subdivided into extrusive and hypabyssal igneous subunits (5a and 5b) and various clastic metasedimentary facies (subunits 5c to 5f).

As defined here, the Petscapiskau Group is confined to the western part of the map area. It occurs to the southeast of the Michikamau Intrusion (Unit 10), between the Sail Lake intrusive suite (Unit 2) to the north, the North Pole Brook Intrusive Suite (Unit 9) to the east and south, and Unit 10 to the west, as a roughly parallelogram-shaped lobe that is approximately 13 km across, 10 km deep and elongated in an east-northeasterly direction. A strip of Petscapiskau Group, 6 km long and 2 km wide, extends north-northwestward from the northwestern corner of the lobe between the Sail Lake intrusive suite (Unit 2) and the Michikamau Intrusion (Unit 10). The unit also occurs farther north as a line of small areas between Units 2 and 10, in, north-northwest and southwest of Fraser Lake.

Age

Age determinations on Petscapiskau Group rocks within the map area (Figure 7) consist of 2045 ± 54 Ma (K–Ar, hornblende, metagabbro, subunit 5b, Fraser Lake; GSC 73-163, Wanless *et al.*, 1974, page 52), 1251 ± 40 Ma (K–Ar, hornblende, mafic metavolcanic rock, subunit 5a, Contact Lake; GSC 76-240, Wanless *et al.*, 1978, page 52), and 1526 ± 50 Ma (K–Ar, biotite, pelitic paragneiss, subunit 5f, Contact Lake; GSC 63-163, Wanless *et al.*, 1965, page 113). All of these dates are thought to represent disturbances by one or more metamorphic events instead of a primary age for the group. The age of the Petscapiskau Group is, therefore, imprecise, and a variety of chronostratigraphic designations have been assigned to it in previous work.

The group was given an Aphebian age by Emslie (1964b, 1965) and Nunn and Noel (1982), a questionably Aphebian age by Emslie (1970), a Paleohelikian age by Emslie (1978c), an Aphebian or Paleohelikian age by Greene (1972, 1974), and was divided into a lower Aphebian component and an upper Paleohelikian component by Emslie (1978a). In this report, Emslie's upper Paleohelikian component has been removed to either Unit 1 or Unit 8 and his Aphebian component (the Petscapiskau Group as defined in this report) designated as Proterozoic I (mostly equivalent to the Aphebian) or older.

Subunit 5a

Mafic metavolcanic rocks, chiefly amphibolite and including pillow lava, hyaloclastite and banded amphibolite.

Distribution

The mafic metavolcanic rocks occur as thin (approximately 60 m) to thick (greater than 3 km) tabular amphibolite layers within the Petscapiskau Group sequence and as an isolated outcrop surrounded by drift to the north of Fraser Lake at the map edge. The thinner layers are oriented in a north- to northwest-trending direction from Contact Lake northward to Hook Lake, and are subparallel and close to the contact with the Michikamau Intrusion (Unit

10). Some of these, together with concordant layers from near the intrusion contact in the same area, and recorded by Emslie (1970, pages 58 and 59) as ranging from 3 to 15 m thick, may be sills of pyroxene-hornfels-facies metagabbro (subunit 5b) or olivine gabbro (subdivision 10a^1) instead of layers of subunit 5a. The thick layer is a minimum of 1 km thick (constrained by faulting and lack of exposure) south of Contact Lake, from which it trends south-southwestward for 5 km, subparallel and adjacent to the Michikamau Intrusion (Unit 10). Here, it strikes away from the intrusion (tracing out a large wavelength fold) to the east, changes to the southeast and east again (each for about 4 km) and generally increases in thickness to 3 km or more. The southeast-trending part of the fold limb is interrupted by a 2 to 3 km dextral offset.

Description

The mafic metavolcanic rocks of subunit 5a consist of green- and, less commonly, grey- or brown-weathering lenticular and layered amphibolite. The layering is commonly defined by a green, dark-grey, and rarely black, colour banding. Layering on a scale of a few centimetres to a few metres is the norm, but massive two- to several-tens-of-metres-thick units are present, especially in the southernmost part of the outcrop area. Both layered and massive parts of the sequence locally have a lenticular form at greater-than-outcrop scale.

Where metavolcanic rocks occur as large exposures, they are commonly characterized by lenticular forms outlined by narrow bands of finer grain size, which are generally associated with a colour change (either lighter or darker) (Plate 30). Characteristically, the lighter outlines are apple-green, cream or yellowish, and are commonly epidotized or rusty weathering. The lenticular forms vary from very indistinct to well-defined pillows in which the colour bands represent selvage and minor interpillow material. Rarely, thin vesicular layers occur just inside the selvages. The vesicles are oval in shape and filled with felsic material or have felsic rims to an unidentified, brown, translucent mineral. Interpillow material includes amphibolite, quartz and carbonate.

Plate 30. *Flattened metabasic pillow lava (subunit 5a). The more prominent light bands having the low-angle discordances are light-coloured selvage material defining the pillows. Photo GN81-CS29-5, locality N150, NTS 13L/4E, GR 5246.9931. Length of hammer is 34 cm.*

Pillows range from small (0.2 by 0.5 m) to large (0.4 by 1 m or more) where deformation is relatively minor and primary shapes are easily discernible. Mostly, however, they are flattened (Plate 30) and range from 1.5 to 2 m long and 0.2 to 0.5 m thick, down to 1 to 3 cm thick and of commonly indeterminate length. In these rocks, the layering occurs as alternations of interior pillow and selvage material on the small scale and as variations in the size and degree of flattening of bundles of pillows on a larger (metre to tens of metres) scale. In the moderately flattened layers, pillow margins and roots may be infolded. Thinner layering of individual pillows appears to increase the proportion of lighter green, selvage-type material in the rock; however, selvage proportions very rarely exceed 40 percent of the whole in the pillow lavas.

Layers characterized by an abundance of the lighter green, selvage-type material (Plate 31) commonly are intercalated with the pillow lavas, but are very rarely dominant and form only a minor percentage of the subunit as a whole. The layers range from centimetres to several metres thick, seem continuous at outcrop scale, and consist of irregular, angular, lenticular to extremely flattened, commonly clast-supported fragments in a darker green amphibolite matrix. These layers are interpreted as hyaloclastites.

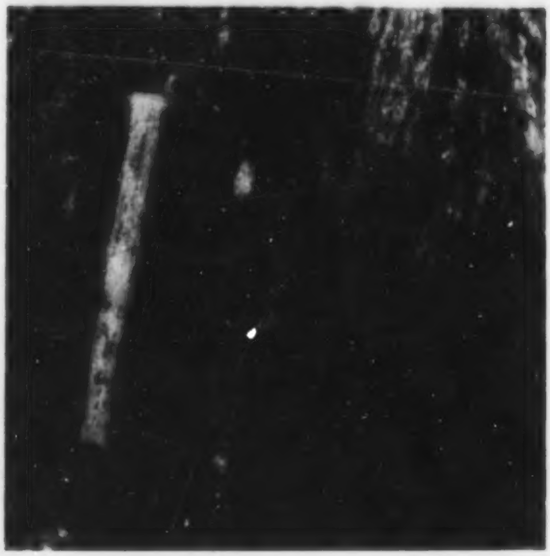


Plate 31. *Metabasic hyaloclastite (subunit 5a) containing deformed quartz segregations and the effects of abundant epidotization and alteration. Photos GN81-CP34-23,24; details from CP34-25, locality G670d, NTS 13L/4W. Length of hammer is 34 cm.*

Rarely, internally homogeneous, massive layers that are 30 to 50 cm thick and continuous for greater than 2 m within or across an outcrop, interdigitate with layers of flattened pillows. These may represent non-pillowed flows or discontinuous sills within the volcanic pile.

Layering is generally defined by internal structural variations (as outlined above) and/or by variations in colour index, colour banding and weathering features. Colour-index variations also occur as patches and streaks rather than as continuous layering.

Mineralogically, most of the rocks are amphibolite (colour index 35 to 65) ranging into mafic amphibolite (colour index 65 to 90). Leucoamphibolite (colour index less than 35) and ultramafic amphibolite (colour index greater than 90) are very rare. The rocks consist of hornblende–plagioclase assemblages ± clinopyroxene, magnetite, biotite, quartz and orthopyroxene. Pyrite is a rare accessory phase. Close to the Michikamau Intrusion (Unit 10), rare calcsilicate layers with pull-apart structures occur in less competent amphibolite. These layers consist of either garnet–diopside–plagioclase–hornblende, or garnet–diopside, and the pull aparts contain either diopside ± porphyroblastic hornblende, or epidote.

The isolated outcrop at the northern map edge consists of interlayered plagioclase–hornblende–garnet–quartz–hypersthene amphibolite and plagioclase–hornblende–diopside–garnet–quartz leucoamphibolite. Clinopyroxene possibly occurs with the hornblende at this locality and is probably also present in much of the dark-grey to black amphibolite found close to the Michikamau Intrusion, which appears to be one- or two-pyroxene granulite.

Rare felsic veins occur in subunit 5a. Discontinuous, folded or boudined quartz veins are the most conspicuous. Close to the Michikamau Intrusion (Unit 10) the veins consist of quartz, quartz and plagioclase, or plagioclase; hornblende veinlets occur here too. On the southeast side of Magnetite Lake, one plagioclase–quartz vein is graphic textured, has a quartz core and contains xenoblastic hornblende. Here also, feldspathic (plagioclase dominated) veins and segregations contain orthopyroxene and rare unidentified, grey and brown, bladed and radiating minerals (anthophyllite or gedrite?). Thin felsic veins and net-vein systems are present in the subunit, and epidote, chlorite, quartz and carbonate patches, streaks, veins and alteration are found throughout, especially in the southern and central areas.

Except in the few areas where an igneous texture is preserved (see below), the amphibolite contains a weak to moderate, penetrative mineral fabric. This is enhanced by: a felsic or ferromagnesian shape fabric; quartz and felsic veining; thin, discontinuous hornblende foliae; veinlets or anastomosing location fabrics; and inhomogeneously developed cleavage in the finer grained amphibolite. The last feature commonly occurs in the selvage and interpillow material, and wraps around pillow structures. Flattening of pillows or pillow-breccia fragments is subparallel to the other fabric elements. Asymmetrical folds of these fabrics are rare.

The groundmass in the amphibolite is mostly fine grained, but ranges down to very fine grained in some finely layered rocks and up to medium grained (to 5 mm) in the thicker massive portions. On the western limb of the large wavelength fold, the amphibolite is commonly spotted, mostly due to a sparse (approximately 5 percent) to moderately dense (approximately 50 percent) scattering of coarser, subequant hornblende crystals or aggregates (mostly 0.3 to 1 cm but up to 3 cm across), but also partly due to small, evenly distributed clots of hornblende in plagioclase or vice versa. Other brown-weathering spots are due to pyrite, Fe oxides and, possibly, disseminated garnet. On the southern limb of the same fold, spotting is rare and consists mostly of 10 to 15 percent, fine- to medium-grained, euhedral to subhedral, relict, porphyritic plagioclase.

The subunit consists primarily of a metamorphic mineralogy (the porphyritic plagioclase may be the only relicts of the original assemblage), although in places a subophitic igneous texture is preserved. Throughout much of the area, hornblende and plagioclase form a granular, subequant, hypidiomorphic texture that has a poor to moderate linear component. Aggregates of hornblende in plagioclase or vice versa are similarly elongated, although the individual mineral components within the aggregate may be isotropic in orientation. Granular, isotropic mineral fabrics and porphyroblastic hornblende are more common near the Michikamau Intrusion. The porphyroblastic hornblende occurs either as individual, equant to weakly elongated, subhedral to very ragged, solid to sieved crystals, or as aggregate replacements that lie randomly orientated on various planar elements in the rock. They may be concentrated in either the regular amphibolite or in the selvage material.

Rarely, plagioclase and magnetite (and/or pyroxene?) are also porphyroblastic minerals: the plagioclase as 1 to 3 mm linear laths in a fine-grained hornblende groundmass, and the magnetite (and/or pyroxene?) as small grains within a fine-grained halo (≤ 4 mm long) of plagioclase. The porphyroblastic mineralogy, aggregates after porphyroblastic minerals, and some of the brown spotting are invariably mimetic on pre-existing features (e.g., the foliation).

Petrography

Amphibolites of subunit 5a contain the essential mineral assemblage hornblende–plagioclase–opaque minerals ± biotite, clinopyroxene, titanite, quartz and epidote. Accessory zircon is rare. Retrograde chlorite is usually present along with carbonate, epidote, quartz and zeolite minerals; these occur either throughout the rock or in veins and vugs. In places, complete retrogression has led to the assemblage quartz–saussuritized plagioclase–chlorite–muscovite–opaque mineral.

Hornblende and plagioclase usually occur either homogeneously distributed or concentrated in layers exhibiting an elongate granoblastic texture that defines the foliation. Biotite enhances the foliation where present, and locally hornblende and biotite have a very strong preferred optical orientation. Hornblende and, less commonly, epidote and titanite, are porphyroblastic and overprint the foliation in many areas.

Structure and Metamorphism

The mineral, shape and location fabrics are invariably parallel and belong to the main episode of foliation development. Locally, however, the layering and flattening in the pillow lavas and hyaloclastites are discordant to the foliation; therefore, a primary flattening and/or a deformation episode is assumed to predate the mineral and shape fabrics. Flattening of the pillows and breccia fragments is very variable, although commonly extreme. The main fabric development occurred at upper-greenschist or amphibolite grade, which is preserved in the southern part of the outcrop area of the subunit. Asymmetric folds of the fabric are rare and developed without new mineral growth.

Around the Michikamau Intrusion (Unit 10), thermal metamorphism produced an aureole and several related structures. The aureole is represented by porphyroblastic growth of hornblende followed by hornblende + plagioclase + magnetite and then pyroxene, in zones approaching the intrusion, and, subsequently, by static recrystallization of the amphibolite groundmass and some early porphyroblasts to produce an isotropic mineral fabric (with earlier fabric elements preserved as shape aggregates). Locally, the hornfels contains leucocratic segregations and hornblende veinlets. Close to the Michikamau Intrusion, metabasic rocks consist of two-pyroxene granulite and, locally, feldspathic and quartzofeldspathic veins and segregations contain orthopyroxene- and bladed minerals (amphiboles?). The random orientation and/or mimetic nature of the porphyroblast growth and groundmass recrystallization near the Michikamau Intrusion indicate posttectonic static recrystallization in the aureole.

Epidote, chlorite, quartz and carbonate veining, alteration, and joint mineralization represent later, low-grade (greenschist facies) tectonic events.

Contact Relationships

The amphibolite is conformably interlayered with rhyolite-porphyry conglomerate (subunit 5c), quartzite (subunit 5e) and pelitic to psammitic metasedimentary rock and paragneiss (subunits 5f and 5ef). It is contact metamorphosed in its western parts by the Michikamau Intrusion (Unit 10).

Subunit 5b

Metagabbro.

Distribution

The metagabbro occurs as isolated outcrops in the south of Fraser Lake, just south of Fraser Lake, and in The Buttress 4 km west-southwest of Fraser Lake. It may be present as conformable layers in the strip of Petscapiskau Group south of Hook Lake.

Description

The subunit is a dark-grey to black, fine- to medium-grained metagabbro. The metagabbro is either very dark, speckled, slightly greenish or brown-weathering. It varies from massive to layered; layering is defined by compositional variations and the presence of thin, continuous or discontinuous, black, ferromagnesian-rich streaks or laminae, weathering differences, and quartz or felsic segregations and veins. The compositional layering consists of gabbro (colour index 35 to 65) and leucogabbro (colour index 10 to 35); the ferromagnesian-rich laminae commonly have colour indices greater than 65.

The metagabbro is composed of plagioclase + hornblende ± garnet ± magnetite and, locally, contains clinopyroxene, orthopyroxene and possibly olivine. (The olivine-bearing layers may be sills of subdivision 10a^1.) The metagabbro apparently consists wholly of a metamorphic mineralogy, represented now by amphibolite or pyroxene granulite.

A subophitic igneous texture is preserved in the outcrop near the south shore of Fraser Lake. Greenish plates of hornblende, probably pseudomorphing clinopyroxene, define a colour index of 25 to 30, and partially enclose recrystallized laths of fine grained granular plagioclase. A similar primary texture may have been present at the nearby island in the south of Fraser Lake, but this garnet-bearing metagabbro is strongly deformed and contains large lineated hornblende aggregates.

The rock is compositionally layered at The Buttress. The main phase is a fine- to medium-grained leucoamphibolite exhibiting a polygonal, equigranular metamorphic mineralogy and containing spots of recrystallized clots of either plagioclase or hornblende. This rock is interlayered with minor, thin, continuous or discontinuous laminae or streaks of hornblende + plagioclase ± garnet, in which the plagioclase forms 1 to 3 mm single grains (rare) or polygonal aggregates (common) in a granular hornblende groundmass. A brownish- or greenish-grey reaction rim occurs between the plagioclase and the ferromagnesian groundmass.

South of Hook Lake, basic rocks, consisting of amphibolite and augite granulite containing hypersthene and/or olivine, form apparently concordant layers in the Petscapiskau Group succession. They exhibit static recrystallization textures throughout, and commonly contain hornblende streaks and laminae, and less commonly, quartz and felsic segregations. The static recrystallization preserves relict-shape-aggregate foliations parallel to these location fabrics. The layers may alternatively belong to the amphibolite (subunit 5a) or, in the case of those containing olivine, be sills of the Michikamau Intrusion (subdivision 10a^1).

Structure and Metamorphism

The metagabbro contains a strong mineral and shape aggregate foliation on the island in Fraser Lake. Elsewhere, only the shape fabrics are preserved, the static recrystallization having destroyed the mineral fabrics; locally, no fabric is prominent and a relict igneous texture is present (outcrop south of Fraser Lake). The shape fabrics are parallel to the ferromagnesian streaking (as well as the interlayering of the subunits) and subparallel to the quartz and felsic veining.

Neither earlier nor later (excepting static recrystallization) structures were observed in the metagabbro.

The static recrystallization is most prominent, and generated coarser grained rocks, in the outcrops between Hook Lake and Contact Lake. It is apparently related to contact metamorphism by the nearby (to the west) Michikamau Intrusion.

Contact Relationships

Possible layers of metagabbro are conformably interlayered with pelitic and psammitic paragneiss (subunits 5f and 5e) between Hook Lake and Contact Lake; however, these exposures may belong to subunit 5a or Unit 10 (see above). All other outcrops are isolated, however, at The Buttress, the metagabbro is also assumed to be conformably interlayered with paragneiss (subunits 5f, 5ef and 5e/f).

Subunit 5c

Rhyolite-porphyry conglomerate.

Distribution

The conglomerate occurs in the nose of the large-wavelength fold 2.5 km east of Magnetite Lake, from which it trends east-southeast for about 4 km as a 0.5- to 1-km-wide tabular layer within the supracrustal sequence. The layer is interrupted by an approximately 2.5-km-dextral offset, then continues on the same east-southeast trend for a farther 2 km. The conglomerate also occurs underlying a prominent hill by the reservoir lakeshore 5 km farther east; it is surmised to be continuous with the other outcrop area.

Description

Subunit 5c is an oligomictic, conglomeratic member of the Petscapiskau Group that is approximately 1 km thick along most of its length. The rock is pinkish-brown, buff or pale-greenish-weathering and dark grey on fresh surfaces. It is internally layered on a scale of a decimetre to many metres, as defined by variations in clast size, clast:matrix ratio, and matrix grain size.

The conglomerate is thickest, coarsest grained and most massive at the two ends of its outcrop area (Plate 32). In these places, massive conglomerate occupies the whole outcrop, with little evidence of internal layering, indicating layer (bed) thicknesses of 5 m or more. The clasts are generally about 5 by 10 cm across and 10 to 35 cm long but range up to 2 m or more in length. They are predominantly a quartz- and feldspar-porphyritic rhyolitic or dacitic lithotype, and were clearly rounded prior to their deformation. The conglomerate is more or less clast supported and has a coarse-grained arenite matrix (about 15 to 35 percent of the rock), which is poorly to moderately sorted.

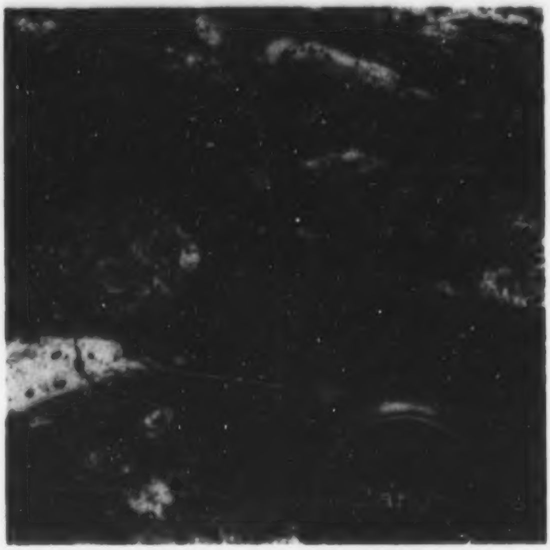


Plate 32. *Subequant microgranite and flattened porphyry clasts in conglomerate (subunit 5c). Photo GN81-CS29-8, locality N156, NTS 13L/4E, GR 5610.0106. Diameter of lens cap is 5.5 cm.*

In the intervening areas, similar, but finer grained, rocks are interlayered with fine- to medium-grained arenite and pelitic schist, which contain scattered to very rare, small porphyry clasts, and fragmental layers of up to 95 percent schistose rhyolitic clasts in a micaceous matrix. In these areas, the subunit is layered at finer scales of a metre or less.

Grading of clast size was observed in a thick layer in massive coarse-grained conglomerate at the southeast end of the subunit, and from a 50-cm-thick cobble layer in coarse-grained arenite at the northwest end of the subunit outcrop. Clast types are almost exclusively of porphyritic rhyolitic rocks, but also include very rare aphyric rhyolite. Microgranite and fine-grained mafic clasts (and a single large clast of leucoamphibolite) occur sporadically. Small, more angular milky-quartz fragments probably reflect disrupted quartz veins rather than clasts.

The porphyry clasts contain variable (but generally homogeneous within any one clast) phenocryst concentrations of approximately 10 to 40 percent. Clear to translucent, 1 to 5 mm, euhedral to subhedral, dark-grey or bright-blue quartz phenocrysts vary from equal to much greater proportion than similar-sized, euhedral to subhedral, white feldspar phenocrysts. The quartz phenocrysts locally contain tiny feldspar inclusions. The groundmass is pinkish to light-green- or white-weathering, grey on fresh surfaces and commonly glassy. Porphyry clasts show minor to extreme flattening, are more or less cleaved, and at one locality, have rare mafic rims. Feathering of the ends of the clasts occurs, most particularly in the clast-rich fragmental layers. More angular rhyolite clasts occur in one outcrop in which they are surrounded by a profusion of flattened porphyry clasts.

Microgranite clasts are equigranular, anhedral in texture, predominantly rounded to slightly oval and mainly undeformed (Plate 32). They occur mostly in the coarser facies of the conglomerate.

Mafic clasts are very fine grained, homogeneous, black to greenish and lenticular to extremely flattened (tuffaceous?), and include rare, or very rare, fine-grained amphibolite. The mafic clasts occur in the central parts of the subunit outcrop area where the facies is finer grained, the clasts sparser and the layering thinner. Hornblende occurs in the clastic matrix in the same area, further indicating a mafic input to the sediment. Syndepositional mafic volcanism is indicated by an interdigitating (westward thinning), up to 2-m-thick mafic layer, rare, thin amphibolite layers and rare mafic rims on porphyry clasts.

The matrix ranges from a coarse-grained arenite containing subangular smaller equivalents of the porphyry phenocrysts, including blue quartz and white or saussuritized pale-green feldspar, to micaceous and quartz−sericite or quartz−feldspar−sericite rocks. The arenite matrix contains a grain elongation and spaced cleavage foliations or is annealed and almost glassy; the micaceous matrix is schistose or phyllitic. Locally, pyrite is an accessory mineral.

Petrography

Porphyritic acid-volcanic, microgranite and quartzite clasts were defined by thin-section analysis of the conglomerate. These clasts occur in a gritty matrix containing detrital grains of quartz, plagioclase, quartzite, acid-volcanic rock and/or chert, microcline and an opaque mineral. The matrix commonly exhibits a bimodal grain-size relationship: the detrital portion (see above), and a very fine grained recrystallized portion that includes quartz, feldspar, green biotite, epidote and opaque minerals ± muscovite ± chlorite. Chlorite appears to be a foliation-forming mineral whereas muscovite is commonly posttectonic and locally porphyroblastic. The foliation is defined by a clast-shape fabric, a detrital-grain elongation, and mineral fabrics defined by some or all of the quartz, feldspar, biotite, epidote, opaque minerals, chlorite and muscovite. Locally, the foliation is better developed and the matrix is differentiated into alternating lithons of quartz + minor chlorite, plagioclase and epidote, and plagioclase + quartz + chlorite + minor opaque minerals, epidote and muscovite.

Structure and Metamorphism

Most clasts and arenite matrices contain a parallel grain-elongation mineral fabric and a weak to strong spaced cleavage. In the finer grained matrices, the foliation is schistose or phyllitic. The fabrics are axial to the feathered clast ends and to rare isoclinal folds of very flattened clasts. These fabrics run subparallel to the subunit layer as a whole. Most quartz veins are disrupted and do not seem to define a fabric. Prefoliation structures have not been recognized unless flattened clasts represent a pre-folding or primary strain.

Locally, the foliation is crenulated. The large-wavelength fold, which the conglomerate layer helps to delineate, and undulations in the fold's southern limb postdate the foliation and are in turn postdated by the fault offsetting the southern limb. Annealing of the arenite cleavage also postdates the foliation and is probably related to thermal metamorphism by the Michikamau Intrusion (Unit 10) in the northwest and by granitoid rocks of the North Pole Brook Intrusive Suite (Unit 9) in the southeast; it is of unknown timing relative to the fault displacement, as is tectonic brecciation that occurred locally at outcrop scale and that formed a breccia of randomly oriented, foliated porphyry clasts.

Contact Relationships

At map scale, the conglomerate is conformably interlayered with amphibolite (subunit 5a) and pelite (subunit 5f). Isolated occurrences of conglomerate in amphibolite and pelite, up to 2 km from the conglomerate layer contact, and of amphibolite in the conglomerate, are taken to reflect this relationship. The conglomerate is probably thermally metamorphosed by the North Pole Brook Intrusive Suite (Unit 9) and the Michikamau Intrusion (Unit 10) where it occurs closest to them.

Subunit 5d

Metagreywacke.

Distribution

The metagreywacke underlies two hills at the eastern edge of the main Petscapiskau Group outcrop area and, possibly, a nearby island to the northeast in Vollant Lake. The hills define two northeasterly elongated areas: a 1 by 3 km area to the northeast and a 0.5 by 1 km area to the southwest.

Description

Subunit 5d is a green- or greenish-grey-weathering, dark-grey metagreywacke that is characterized by an abundance of irregular and folded quartz veins and segregations. The coarser component in the greywacke is fine- to medium-grained, wavy-bedded, generally 3- to 18-cm-thick sandstone, whereas the pelitic component forms discontinuous, recessive-weathering layers up to 6 cm thick. The sandstone is composed primarily of quartz, feldspar and muscovite, and has a gritty, bimodal texture that includes slightly coarser, grey quartz eyes and rare feldspar. The pelitic material is composed of quartz, sericite and chlorite. Rare, green amphibolite and epidotized layers occur in the southern outcrop area. In the south-facing cliff of the northeastern hill, pinkish and green rocks are interbanded over short distances, and some of the subunit may be fragmental (e.g., locally, it appears much like the finer grained clast-bearing facies of the subunit 5c conglomerate). The compositional layering and the quartz veins are undulose or folded.

The northeast hill contains abundant spotting due to porphyroblast growth. The most prominent spots consist of andalusite laths that are pinkish or grey, approximately 2 to 4:1 in elongation and generally to around 6 mm long (but up to 1 by 20 mm), and possible pseudomorphed cordierite represented by green to dark-grey, rounded, oval or rectangular, commonly ragged, sieved, felted aggregates. Amphibole(?) or staurolite(?) laths and rhombs, with ragged ends and felsic inclusions, black biotite and green chloritoid also form porphyroblastic clots in this area. The chloritoid occurs at the west end of the outcrop and the cordierite(?) at the northeast corner. The southwestern hill contains red-brown hematite spots distributed in layers. In Vollant Lake, the interlayered pelitic and psammitic components are very contorted.

Quartz veins and segregations developed throughout the metagreywacke are very contorted, folded and disrupted. They occur as thin, isoclinally folded ribs, or thicker, boudinaged, necked or tightly folded veins up to 6 cm across; the foliation is axial planar to these folds. Asymmetric refolding of the veins and folding of the foliation is also present. The veins and segregations are almost exclusively quartz, which occurs as milky, granular, subequant grains (0.5 to 1 mm across and, rarely, larger). Commonly, the veins contain muscovite, and on the northeastern hill, minor feldspar, chlorite and specular hematite occur locally. Pinkish andalusite is developed in some veins.

Petrography

The outcrops of metagreywacke occur close to the assumed contact with the North Pole Brook Intrusive Suite (Unit 9). Supporting petrographic evidence for this occurs in the predominantly pelitic rock, where a relict crenulated foliation, defined by an opaque mineral and quartz veins, is randomly overprinted by a chlorite–muscovite mesh that is studded by chloritoid, tourmaline and muscovite porphyroblasts.

Structure and Metamorphism

The main foliation is a grain-elongation mineral fabric in the sandstone and a phyllitic schistosity in the pelitic rock types. Most folded or disrupted quartz veins and folded layering are subparallel or parallel to this foliation, although the quartz veins and segregations represent an earlier fabric.

The foliation is postdated by asymmetrical folding, and the quartz veins are refolded. The porphyroblastic minerals overprint the foliation and bedding planes randomly or mimetically and are the result of a thermal metamorphic overprint. A breccia of angular green clasts, other fragments and quartz blebs is probably a later tectonic feature.

Contact Relationships

The metagreywacke is not in exposed contact with any other unit, but it is probably intercalated in the Petscapiskau Group with pelite (subunit 5f) and may be a facies variant of the conglomerate (subunit 5c) or an interbedded facies of psammite and pelite (subunit 5ef). The porphyroblast growth is probably related to thermal metamorphism induced by the intrusion of North Pole Brook Intrusive Suite granitoid rocks (Unit 9), which, therefore, has been interpreted to underlie the drift just to the east of the two hills.

Subunit 5e

Quartzite, psammite and minor quartz-pebble and polymictic conglomerate.

Distribution

Subunit 5e occurs as scattered outcrops within an irregular, approximately 6 by 2.5 km, easterly elongated ovoid area immediately southeast of the contact with the Michikamau Intrusion (Unit 10) on the east shore of Michikamau Lake. The southern margin of this area is a fault that has a 0.5- to 2-km-dextral offset, across which a contiguous, east-southeasterly elongated, 4 by 2 km area is interpreted to be underlain by subunit 5e, although unexposed. Smaller areas and layers, 100 to 500 m wide and 0.3 to 2.0 km long, are interlayered with amphibolite (subunit 5a) and pelite (subunit 5f) between Magnetite and Hook lakes and on the islands in Fraser Lake. In the former region, these areas are elongate north-northeasterly, northerly and northwesterly, whereas in the Fraser Lake region they are more or less equant.

Subunit 5e divides into two members: one dominated by white quartzite, the other by grey psammite. The quartzite occurs from Contact Lake south and southwestward near the southeastern margin of the Michikamau Intrusion (Unit 10), primarily around Contact Lake, at the south end of Magnetite Lake and farther south near the shores of Michikamau Lake. It also forms a few inclusions in leucotroctolite about 1 km west of the large gossan between Hook Lake and The Buttress. The psammite member occurs exclusively in and to the north of Contact Lake, mainly near Hook Lake and on islands in Fraser Lake.

Description

The quartzite is white and rarely grey, pale pink, pale green or yellow brown in both fresh and weathered states. It forms wavy- or plane-sided, tabular, bedded rocks. Bedding is on a scale of 1 to 60 cm, and includes millimetre- to centimetre-scale internal laminae. Parallel lamination and rare, poorly developed cross-lamination define the internal layering. Colour changes and packets of similar bedding thickness occur in cycles of 10 to 30 cm in thin-bedded sequences and at a metre scale in thicker bedded sequences. Laminations and thinly bedded packets are commonly tightly folded. The quartzite is pure, or is dusted with magnetite, or is slightly feldspathic; locally, it contains sillimanite. South of Magnetite Lake, rare pale-pink and pale-green layers, 10 to 20 cm thick, are internally poorly laminated and contain small amounts of garnet and diopside(?), respectively, and are slightly calcareous in places. Between Magnetite Lake and Contact Lake, the quartzite is thick and massive, contains rare thin beds, and weathers yellow-brown due to the presence of large poikilitic garnet. Porphyroblastic sillimanite occurs south of Magnetite Lake and in rusty-weathering inclusions west of the gossan between Hook Lake and The Buttress. In the Magnetite Lake area, muscovite–chlorite and undetermined greenish clots or porphyroblasts occur, and ferromagnesian spots (garnet, an opaque mineral and biotite(?)) have felsic haloes. Between Hook Lake and The Buttress area, pale-lilac cordierite, grey, brown and translucent laths and needles, and dark-grey spots are present. Quartzite on the island, by the shore of Michikamau Lake, is moderately thickly bedded and contains rosettes of black tourmaline on some bedding planes (Plate 33).

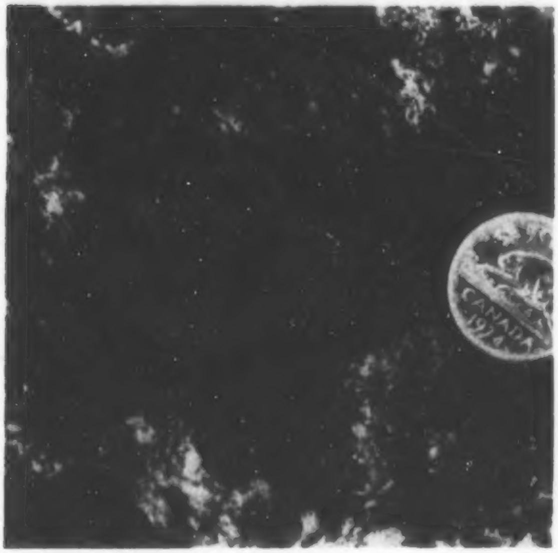


Plate 33. *Stellate rosettes of black, acicular, porphyroblastic tourmaline on quartzite bedding plane (subunit 5e). Photo GN81-CS27-35, locality G584, NTS 13L/4W, GR 4552.0155. Diameter of coin is 2.1 cm.*

The quartzite is interbedded with similar to thicker bedded, gritty subarkosic arenite, containing angular quartz and minor feldspar grains up to 4 mm across in a fine- to medium-grained groundmass, and thin, pelitic laminae. The subarkosic rocks are commonly more yellow weathering than the quartzite, and, along with other poorly laminated rocks such as quartz grit, garnet quartzite and the pale-pink and pale-green layers, form more competent units in the quartzite sequence. Necking and boudinage of the competent layers enhance the undulose bedding in the adjacent quartzite. The subarkosic rocks contain porphyroblastic biotite (clots), minor garnet (sieved) and muscovite. Rounded to flat ovoids of dark-grey to brown, partially recrystallized single grains or granular aggregates (porphyroblastic cordierite(?)) are also distributed in layers.

The pelitic laminae are mostly less than 2-mm-thick (rarely up to a centimetre thick) layers of mica schist mainly consisting of quartz, biotite and muscovite. Pelitic laminae are commonly discontinuous over distances of greater than 30 cm. Mica-rich laminae are tightly folded and crenulated, and contain isotropically oriented or mimetic andalusite (up to 3 by 10 mm), and rare, grey to white, random sillimanite needles (aspect ratios of 5 to 10:1). These laminae exhibit a strong mica mineral fabric and are cut by massive, irregular quartz veins. Pelitic laminae also contain or are composed of unidentified blue-grey and greenish to brownish platey minerals. Pelitic material also rarely forms 1- to 2-mm-thick lenses and patches that are up to 4 cm long (rip-up clasts?) in recessive-weathering quartzite south of Magnetite Lake. The lenses are composed of a black, non-magnetic granular mineral and a very similar brown mineral that forms up to 50 percent of a lens.

Conglomerate also occurs in the quartzite sequences. South of Magnetite Lake, a monomict, milky-quartz, granule to pebble, clast-supported, white conglomerate with a quartz arenite matrix occurs with the quartzite and subarkosic arenite. On the island by the shore of Michikamau Lake, a polymict, clast-supported, subrounded to angular, white granule conglomerate occurs with quartzite and thin pelite laminae. The clasts consist mostly of milky quartz and quartzite, a fine-grained light-grey-weathering rock, minor pink (and rarely white) feldspar (up to 4 mm across), and rare pelite clasts containing a profusion of random sillimanite needles. The matrix is composed of bimodal, angular to subangular grit, which has a minor greenish pelitic component, and better sorted, subrounded quartz arenite.

Quartzite, arenite and conglomerate contain a clast- or grain-elongation fabric and, more rarely, a fracture cleavage. Individual quartz grains and recrystallized aggregates are mostly composed of angular to subangular grains or xenomorphic crystals about 1 mm across. Relatively regular to very irregular milky-quartz veins, patches and fracture fills are common. The outcrop 2 km south-southeast from the south end of Magnetite Lake contains profuse quartz-filled fractures and is almost a tectonic breccia; the fractured rock has a greenish stain.

The psammite is a buff-, grey-, brown- or rusty-weathering, dark-grey quartzofeldspathic arenite forming centimetre- to decimetre-scale, wavy-margined tabular layers. Internal lamination is less common and less prominent than in the quartzite.

The psammite is mainly composed of fine-grained quartz and feldspar, and a small pelitic component, which contains varying, but generally minor, proportions of biotite, sillimanite, cordierite, garnet, pyroxene or hornblende, iron oxides and pyrite. Pyrite is a common accessory mineral and psammitic layers containing garnet, oxides or sulphides are commonly rusty weathering. Some psammitic layers contain abundant spotting due to porphyroblastic growth of pyroxene, garnet, biotite, hornblende(?) and iron oxides, which are commonly surrounded by rusty haloes.

On the islands in Fraser Lake, the psammite forms thick homogeneous units containing little apparent bedding. Internally, however, the psammite is commonly strongly differentiated. Quartz is segregated into a fine, discontinuous, narrowly anastomosing ribbing parallel to (and enhancing) the foliation. Feldspar, cordierite, biotite and quartz ± sillimanite and garnet occur between the ribs and may mimetically reflect a foliation or primary lamination. Biotite forms restite schlieren. The sillimanite, cordierite and garnet form coarse metamorphic porphyroblasts; sillimanite, in particular, occurs as large (to 1 by 4 cm), grey-green, random laths. Locally, the quartz ribbing is pinched in incipient boudinage structures. Less differentiated layers also are commonly coarsely or finely spotted by porphyroblast growth. In places, larger, more typical quartz-segregation veining is present, but these thicker, irregular veins are rare in comparison to those in the interlayered pelitic rocks (see subunit 5f below).

The psammite is interbedded with thin mica- and cordierite-rich pelite. In the Fraser Lake area, the pelite commonly contains coarse-grained, grey sillimanite laths.

Petrography

In the southernmost localities of the subunit, the quartzite and conglomerate contain minor proportions of green biotite, chlorite, muscovite and tourmaline, whereas the pelitic clasts contain actinolite + green biotite + chlorite + opaque minerals + titanite + tourmaline + garnet, and the pelitic laminae between the arenite layers contain quartz + green biotite + feldspar + andalusite(?) + pinnite(?) + tourmaline + opaque minerals + chlorite.

Close to the southern edge of the Michikamau Intrusion (Unit 10), quartzite and subarkosic arenite consist of assemblages such as quartz ± feldspar ± saussuritized feldspar (or white mica) + opaque minerals ± muscovite ± tremolite, cordierite + sillimanite + opaque minerals, and quartz−plagioclase−muscovite−brown biotite−opaque minerals + cordierite ± tremolite ± zircon. The tremolite, the brown biotite, some of the muscovite and the cordierite and sillimanite are porphyroblastic. Locally, biotite is altered to chlorite and chlorite and muscovite or muscovite and carbonate occur together as alteration products. At the north end of Magnetite Lake, a similar assemblage includes garnet.

Farther north, the subunit consists mostly of psammite rather than quartzite and also crops out very close to the contact with the Michikamau Intrusion. In these areas, the non-quartzofeldspathic minerals are characterized by brown and red-brown biotite, hypersthene, opaque minerals and zircon ± garnet and chlorite. Orthopyroxene is commonly poikiloblastic and biotite is intergrown with, or overgrown by, a vermicular mixture of biotite and a felsic mineral. Chlorite and, locally, muscovite and carbonate are retrograde products.

Structure and Metamorphism

The quartzite, arenite, grit and conglomerate contain a well-developed grain-elongation mineral fabric, the conglomerate contains a clast elongation, and the pelitic laminae contain a strong mica fabric; these define the main foliation in the quartzite-dominated part of subunit 5e. Rarely, the grain elongation in quartzite displays a good lineation. The felsic mineral fabrics are axial planar to tight to isoclinal folds in the thinly bedded, well-laminated quartzite. Also, necking and boudinage of the more competent layers in the sequence relate to the main deformation.

The bedded psammitic rocks contain a weak felsic mineral fabric, and the intervening pelite has a strong biotite foliation. In the more homogeneous psammite from the Fraser lake area, the main foliation is represented by quartz ribbing, biotite schlieren, mimetic biotite and other minerals, and, locally, by a mimetic location fabric. Tight to isoclinal folds of the rare, thicker, irregular quartz veins are associated with the fabric development.

In the psammitic portion of the subunit, these larger quartz veins, and perhaps the finer ribbing, represent an earlier tectonic segregation. No relicts of earlier structures have been recognized in the quartzite and associated rocks.

Later structures occur as rare asymmetric and more open folding of the bedding and the main foliation, the localized development of a fracture cleavage in pelitic or arenaceous rocks, and a pervasive crenulation of the mica foliation in the pelitic laminae. Not all the later folds are structurally compatible with the crenulation development; therefore, there must be more than one generation of later folds. (Whether or not the incompatible folds came before or after the crenulation-associated folds is unknown.)

Other late structures include a host of quartz veins and fracture fills, and, locally, tectonic breccia containing a quartz matrix. Some of these structures are related to the folding of uncertain relative age, but most are of unknown affinity although many predate the posttectonic recrystallization (see below).

Static recrystallization has affected the whole subunit to some degree. In the southernmost exposures, pelite clasts are replete with amphibole, the main foliation is overgrown by randomly oriented andalusite, green biotite and chlorite, and at one locality, quartzite bedding planes are mimetically overgrown (Plate 33) by rosettes of tourmaline (the last is probably a replacement of very thin and discontinuous pelitic partings). Throughout the rest of the subunit, the whole of the non-felsic mineralogy and most quartzofeldspathic minerals have been posttectonically recrystallized during thermal metamorphism by the Michikamau Intrusion (Unit 10). Many early structures are only preserved because of their original compositional differentiation or because of the mimetic aspect of minerals like micas and sillimanite.

Porphyroblastic minerals include cordierite, sillimanite, garnet, biotite, andalusite and iron oxides. Quartz, feldspar, muscovite and a variety of unidentified minerals have also recrystallized or crystallized. The muscovite–chlorite clots south of Magnetite Lake, in an otherwise high-grade zone of the aureole, indicate localized later replacement at a lower grade.

Contact Relationships

Subunit 5e is conformably interlayered with amphibolite (subunit 5a), interbedded pelitic and psammitic paragneiss (subunit 5ef) and pelitic paragneiss or metasedimentary rock (subunit 5f). It is intruded by tonalitic dykes (Unit 6) on Rusty Island in Fraser Lake and by the Michikamau Intrusion (Unit 10) west of the gossan between Hook Lake and The Buttress. In addition, all exposures of subunit 5e lie within the aureole of the Michikamau Intrusion and have undergone variable to complete recrystallization.

Subunit 5f

Pelitic schist or phyllite and pelitic to semipelitic paragneiss.

Distribution

Pelitic rocks from the largest subunit in the Petscapiskau Group. The subunit forms a subrectangular, 5 by 10 km area with Contact Lake at its northwestern corner, and a contiguous, unexposed, 5 by 2 km triangular area to the south, across a 1 to 3 km dextral offset. It includes well-exposed, 0.3- to 1-km-wide intercalations within the supracrustal sequence between Contact Lake and Hook Lake that trend northerly to northwesterly. Well-exposed parts of the subunit also occur in a 1 km^2 area between amphibolite, quartzite and an interbedded pelite and psammite facies (Petscapiskau Group subunits 5a, 5e and 5ef, respectively) in the nose of the large wavelength fold, and form small (up to 1.2 km long) subequant or oval areas on the islands in Fraser Lake and near the map edge 7 km north of Fraser Lake. The first of these well-exposed areas is extrapolated as a 0.5-km-wide layer eastward along an unexposed ridge for 1 km, dextrally offset several hundred metres, and extrapolated for an additional 1 km.

Description

Subunit 5f consists of a grey-weathering, dark-grey, fine- to medium-grained, pelitic schist or phyllite and a brown-weathering, dark-grey, medium- to very coarse-grained, pelitic to semipelitic paragneiss. The schist is composed of mica, quartz and feldspar, contains a well-developed, crenulated foliation, and is characterized by irregular milky-quartz veins. It is easily weathered and forms rare, small, homogeneous outcrops in the north-central part of the lobate extension of the Petscapiskau Group southeast of the Michikamau Intrusion (Unit 10). In contrast, the paragneiss occurs as numerous, large, high-relief, massive outcrops in the discontinuous belt of subunit 5f exposures immediately to the east of the Michikamau Intrusion.

In the northernmost outcrops and throughout Fraser Lake, paragneiss occurs as dark-grey, commonly greasy, cordierite-rich rocks (e.g., Plate 1A of Emslie, 1970) containing sillimanite, quartz and feldspar ± biotite, garnet and andalusite along with more quartzofeldspathic (semipelitic) compositions, in which garnet is common. Sillimanite-rich rocks commonly contain a coarsely anastomosing fabric of centimetre-thick, discontinuous quartz veins between which the sillimanite occurs as isotropically oriented, greenish-grey laths up to 5 cm long in a groundmass of cordierite, quartz, feldspar and biotite. Farther south, between The Buttress and Contact Lake, similar rocks also contain orthopyroxene, both as scattered grains and as veins, and felsic veins are composed of quartz and/or plagioclase.

Around Contact Lake, the paragneiss is generally more micaceous and contains far more andalusite and much less sillimanite. It is a cordierite-spotted schist south of Magnetite Lake. The paragneiss is layered (Plate 34). At scales of centimetres to decametres, mineralogical variations occur in the pelitic rocks or result in semipelitic layering within the pelite

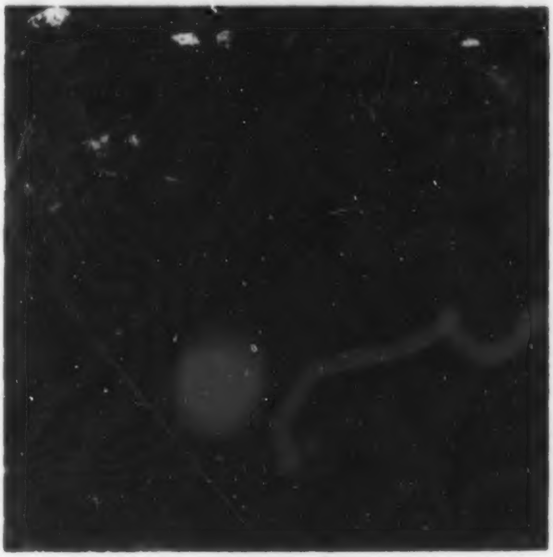


Plate 34. *Massive, brown-weathering well-bedded cordierite–sillimanite paragneiss containing rare quartz segregations (subunit 5f); aureole of the Michikamau Intrusion (Unit 10). Photo GN81-CP36-10, locality G690 (The Buttress), NTS 13L/SW, GR 4666.2382. Length of hammer is 34 cm.*

pelite and, less commonly, vice versa; at similar scales, dark-grey- or rusty-weathering layers occur. Rare, thin psammite layers are also present locally. These occur as necked, sillimanite-bearing layers (up to 2 cm thick) and form up to 10 to 15 percent of the rock at The Buttress. The layering is enhanced throughout by irregular felsic veins. Paragneiss between, or lacking, the schistose, micaceous layers, has a range of fabric development from isotropic to coarsely foliated.

Petrography

In the centre of the lobe of Petscapiskau Group rocks to the southeast of the Michikamau Intrusion (Unit 10), the pelites are strongly foliated metasedimentary rocks composed of the assemblage quartz–microcline–chlorite–biotite–plagioclase–opaque minerals–epidote ± amphibole ± tourmaline. Locally, muscovite is a significant component. Quartz ribbons, biotite and opaque minerals form a foliation and tourmaline probably crystallized at this time too. Some chlorite defines another possible fabric, either as strain-slip relicts between the main biotite foliae or as crenulations of these foliae; the chlorite may also be synchronous with the main biotite–opaque mineral foliation. Epidote and amphibole are posttectonic porphyroblasts, and some chlorite and muscovite are random or mimetic replacements of other minerals, e.g., biotite and amphibole.

In the aureole adjacent to the Michikamau Intrusion (Unit 10), rocks vary in fabric development from isotropic to foliated; however, the foliation is due to preservation by mimetic growth during development of the aureole. Mimetic growth is also strongly controlled by the compositional layering, which is subparallel to the foliation (see below). All rocks contain cordierite or quartz + plagioclase as their major component. Cordierite occurs alone or with quartz and/or plagioclase; these minerals commonly dominate alternating layers. Everywhere that cordierite is absent, quartz and feldspar occur together. Other minerals commonly forming significant proportions of the rock include sillimanite, hypersthene, garnet and red-brown biotite, which, together with the cordierite and spinel, form the index minerals in the assemblage. Microcline, myrmekite, opaque minerals and epidote are commonly present, zircon is an accessory phase, and muscovite and minor chlorite are later alteration products.

Cordierite is poikiloblastic and commonly displays either sector or lamellar twinning. Sillimanite either forms massive poikiloblasts or is replaced by fibrolite. Garnet is usually anhedral and surrounded by biotite-poor haloes. An opaque mineral rarely is cored by epidote and commonly is rimmed by garnet or biotite; it also occurs in clots with sillimanite. Disseminated clusters of green spinel with associated opaque mineral ± epidote, either form a crude halo around sillimanite or occur as subrectangular clots in pinitized cordierite porphyroblasts, but are everywhere separated from sillimanite by cordierite rims. These areas are always free of biotite. Locally, plagioclase is antiperthitic; in many places, K-feldspar has not been identified but myrmekite is present and locally abundant.

Structure and Metamorphism

The feature common to both the schist and the paragneiss, and commonly the most striking structural feature in the rock, is the felsic veining (e.g., Plate 1A of Emslie, 1970, southwest of Hook Lake). In the schist, the veins are composed of milky quartz, whereas in the paragneiss they are composed of dark-grey to milky quartz, quartz + feldspar (± biotite) and, less commonly, plagioclase only. The veins are contorted, discontinuous and very irregular in thickness, and commonly are isolated in patches up to 10 cm thick. Most belong to a pre-foliation event and are broadly subparallel to both the compositional layering and the foliation.

The foliation is axial planar to tight to isoclinal folds of the felsic veins, and occurs as an irregular fracture cleavage within the veins. The veins were also flattened, necked and boudinaged at this time. In the pelitic schist, the foliation forms a well-developed mica schistosity or cleavage; in the paragneiss, it is replaced by coarse-grained mimetic crystallization, particularly of biotite and cordierite, and is also probably represented by the anastomosing quartz vein ribbing.

Rare asymmetric folds affect the compositional layering, the foliation and the veining, and, in the schist, the mica foliation is crenulated by one or more events. Large-scale regional folding postdates the foliation and predates the mimetic recrystallization; it may relate to some of the smaller scale structures.

Widespread mimetic to randomly oriented recrystallization in the paragneiss is responsible for the bulk of its mineralogy. Orthopyroxene laminae, and possibly quartzofeldspathic and plagioclase-only veins, mimetically define the compositional layering. Biotite and cordierite are mostly mimetic along the layering or the foliation, but may be isotropic in orientation. Sillimanite, andalusite, garnet, orthopyroxene and quartzofeldspathic minerals are mainly isotropically textured, but may form planar mimetic fabrics. In general, within the paragneiss, orthopyroxene-bearing assemblages and segregations occur only very close to the Michikamau Intrusion (Unit 10), and andalusite-bearing assemblages are more abundant farther away. The paragneiss is regarded as the equivalent of the pelitic schist, within the aureole resulting from contact metamorphism by the Michikamau Intrusion.

Map-scale faulting postdates all other structural and metamorphic events in the subunit.

Contact Relationships

The pelitic rocks are interlayered with amphibolite (subunits 5a and 5b), quartzite and psammite (subunit 5e), and interbedded pelitic and psammitic metasedimentary rocks or paragneiss (subunit 5ef), and occurs in probable conformable sequence with conglomerate (subunit 5c) and metagreywacke (subunit 5d), although actual contact relationships are not exposed. The subunit is of unknown relationship to older units but is intruded by tonalitic dykes (Unit 6) and the Michikamau Intrusion (Unit 10).

Subunit 5ef

Interbedded pelite and psammite or quartzite.

Distribution

This subunit occurs as 0.5 by 1.5 km, northerly elongated areas south of Magnetite Lake and east of Contact Lake, as north-northwesterly oriented layers between Hook Lake and Contact Lake, and as a 1 by 0.5 km triangular area on the large island in the north of Fraser Lake. It also outcrops at the west end of the ridge named The Buttress (4 km west-southwest of Fraser Lake), and as an outcrop near the southwestern corner of Fraser Lake. In many of these areas, it is associated with areas or layers of quartzite and psammite (subunit 5e) and pelite (subunit 5f).

Description

The interbedded facies is dominated by either psammite and/or quartzite, or pelite, and each contains from 15 to 50 percent of the other rock type. (All of subunit 5e contains pelitic laminae and much of subunit 5f contains psammite layers, but in these cases the subsidiary rock type forms less than 15 percent of the whole.)

The massive brown-weathering outcrops south of Magnetite Lake consist of 1- to 25-cm-thick beds of spotted pelite interlayered with approximately equal proportions of 0.5- to 10-cm-thick (rarely up to 25 cm) psammite layers. The pelite is dark grey to pale green, micaceous, commonly feldspathic, spotted with andalusite and sillimanite (and possibly other minerals), and cut by abundant milky-quartz veins. The quartz veins are tightly folded and ribbed along their margins, and internally contain lineated aggregates of either medium-grained polygonal or coarse-grained anhedral quartz. Andalusite forms stumpy to bladed, brown, pink or dark-grey, random or mimetic spotting, and in low-strain areas adjacent to quartz veins, it commonly forms large pink laths in isotropic-textured knots and patches. Sillimanite occurs as white to grey or bluish-grey laths (ranging from 3 to 10:1) that are generally random and more common in the northern part of this area. Coarse dark-grey spots might be andalusite or cordierite, dark-grey to greenish spotting might be cordierite, pyroxene or amphibole, and white, subequant spots may be feldspar. Spotting within the pelitic rocks is commonly coalesced in patches or in ribbons along the layering, and in places is replaced by muscovite. The spots grow across a crenulated mica cleavage or schistosity. Quartz veins are necked or boudinaged and are irregular in thickness, and the mica foliation wraps around them; thicker semipelite layers are also necked, imparting a nodular character to the foliation.

The arenaceous rocks south of Magnetite Lake comprise quartzite and feldspathic psammite, either of which locally contains dark-blue-grey to black magnetite ± sillimanite. Quartzite is parallel-laminated or, rarely, crossbedded, and contains magnetite-rich or muscovite partings on the foresets and laminae, and thin pelitic interbeds. Thinner quartzite beds (0.5 to 2 cm) are dark grey, plane sided and continuous; thicker ones (up to 25 cm) are light grey, grey-brown or greenish, and lenticular or necked. The psammite is grey or cream and similarly laminated or necked. Laminated quartzite exhibits tight to isoclinal folding of the laminae. Thicker psammite and quartzite contain quartz-filled pull-aparts and quartz veining, and toward the north of this outcrop area, the veins include minor feldspar and garnet. Spotting in these psammites is similar to that in the pelite, but smaller in size and much less commonly lath like. It grows across the laminae and the foresets (but may also coalesce along them), and commonly includes coarse-grained muscovite or micaceous clots. In some beds, the spots increase in size or number toward, or are concentrated along, one bedding boundary, indicating an original increase in mud content or grading across these layers.

On the islands and peninsulas in the east of Contact Lake (adjacent to layers of subunit 5e quartzite), thin (0.3 to 2 cm), parallel-laminated, white to grey quartzite makes up 30 to 50 percent of the sequence. It is interbedded with 1 to 40 cm, garnetiferous, grey psammite and 0.1 to 5 cm, dark-grey pelite. Away from the layers of subunit 5e, the proportion of quartzite in subunit 5ef decreases abruptly, and psammite and pelite are interlayered. Psammite is predominant passing westward; elsewhere pelitic rocks are most abundant. Most rocks are brown-weathering due to the presence of garnet or pyrite. The pelite consists of quartz–biotite–muscovite–feldspar–andalusite ± sillimanite, and disseminated pyrite is ubiquitous. Andalusite occurs in large aggregates or as scattered prisms up to 1 cm long, and sillimanite occurs as thin slivers. Some of the pelite is strongly segregated into quartz-rich and mica-rich laminae. Quartzofeldspathic veins parallel the layering and some contain garnet. Quartz veins are discordant or concordant, tightly folded, discontinuous, and coarser grained than the quartzite. Quartzite and psammite contain a generally weak grain elongation and the pelite has a strong mica or quartz–mica foliation. Asymmetric folding is common in the interlayered sequence. In particular, the quartzite layers form outcrop-scale, tight, angular to rounded, limb-attenuated folds.

Between Hook Lake and Contact Lake, feldspathic psammite forms 15 to 30 percent of a pelite-dominated sequence. The psammite forms grey, brown-spotted, massive, quartzofeldspathic rocks containing minor orthopyroxene and cordierite and quartz veining. The pelite is a brown-weathering, dark-grey, cordierite-rich, cordierite–feldspar–biotite ± quartz ± orthopyroxene rock containing black to dark-brown pyroxene veins and abundant felsic veins. Locally, cordierite is replaced by orthopyroxene with leucocratic rims. Felsic veins are commonly irregular and folded, necked or discontinuous.

On the island in the north of Fraser Lake, cordierite-rich pelitic layers containing biotite, sillimanite and garnet (up to

0.7 by 3 cm) predominate over quartzofeldspathic psammite containing garnet, biotite and a brown spotting (probably pyroxene). Across a 25 m measured section, pelite ranges from 0.3 to 12 m thick and forms 80 percent of the sequence; the psammite ranges from 0.2 to 3 m thick. The rocks are grey or greenish grey and greasy, and commonly are brown- or rusty-weathering. They contain a platey foliation in the psammite and a coarsely anastomosing fabric in the pelite (Plate 35) together with quartz and felsic veins. In the psammite, garnet and the brown spots are mimetic and grow as flattened porphyroblasts across biotite-rich seams. In the pelite, the garnet and sillimanite grow in isotropic-textured patches between the anastomosing quartz-vein and mimetic cordierite–biotite foliation.

Plate 35. *Thin quartz platelets and thicker felsic segregations anastomosing around coarse knots of random, porphyroblastic, blue-grey sillimanite in pelitic paragneiss (subunit 5ef); aureole of the Michikamau Intrusion (Unit 10). Photo GN81-CP37-19, locality G718h, NTS 13L/5E, GR 5485.2865. Diameter of coin is 2.5 cm.*

At the west end of The Buttress, 1- to 6-cm-thick layers of fine-grained, yellow-brown-weathering, sillimanite-bearing, feldspathic psammite form up to 40 percent of the sequence (e.g., Plate 1B of Emslie, 1970; Plate 36, this report). The psammite is either homogeneous and sugary textured or contains a pale-bluish-grey to white platey foliation that anastomoses around coarse-grained porphyroblastic clots. They are interbedded with thick, massive, brown-weathering sillimanite- and cordierite-rich pelite containing quartz veins. Outcrop-scale chevron folds and interference patterns are present, and the psammite layers exhibit parasitic folds, mullions and pelitic cleavage flames associated with a weak axial fracture cleavage (Plate 36).

Near the southwestern corner of Fraser Lake, dark, mica-rich pelite is interlayered with lighter coloured psammitic rocks. The pelite contains biotite foliae, schlieren and patches, and folded quartz veins. The psammite contains feldspathic layers, saussuritized plagioclase and epidote alteration.

Structure and Metamorphism

The interbedded facies contains the same fabric elements as the quartzite or psammite (subunit 5e) and the pelitic rocks (subunit 5f). These fabrics have been described with those subunits.

Plate 36. *Interbedded pelitic and psammitic paragneiss (subunit 5ef) having asymmetric folds containing a weak axial planar fracture cleavage; aureole of the Michikamau Intrusion (Unit 10). Photo GN81-CP36-14; locality G690 (The Buttress), NTS 13L/5W, GR 4615.2495. Length of hammer is 34 cm.*

Contact Relationships

The interbedded facies is interlayered with amphibolite, quartzite or psammite, and pelitic rocks (subunits 5a, 5e and 5f, respectively) within the Petscapiskau Group succession. It is confined to the aureole adjacent to the Michikamau Intrusion (Unit 10) and has been contact metamorphosed by the intrusion.

Granitoid Rocks (Unit 6)

Gneissic tonalite dykes.

Definition and Division

Unit 6 consists of tonalite sheets and dykes and is defined here as those rocks with a clear-cut intrusive relationship to the Petscapiskau Group (Unit 5).

Age

The age of Unit 6 is unknown; however, it postdates the supracrustal rocks of the Petscapiskau Group but predates the major regional metamorphism in these same rocks.

Distribution

The tonalite intrusions occur on Rusty Island in Fraser Lake in the northwest quadrant of the map area.

Description

The unit consists of a 20-m-thick orthogneiss sheet, and several, approximately 1-m-thick dykes oriented in a generally northwesterly direction. These rocks are buff-weathering, cream to grey, medium-grained leucocratic tonalites. Biotite and orthopyroxene are scattered as ferromagnesian spots throughout the quartzofeldspathic minerals, which have a coarse-grained, subequant, polygonal granoblastic texture.

The orthogneiss sheet contains a weak gneissosity defined by quartz–feldspar and quartz veins. Quartz veins also cut the dykes, which are otherwise more homogeneous. Both the sheet and the dykes contain biotite-rich schlieren, especially near their margins; these country-rock 'screens' enhance the gneissosity.

The dykes are mostly subparallel to, and partly strongly oblique to, the layering in the host supracrustal rocks. They are folded or gently warped, necked and boudinaged. Small shear zones cut through the dykes and their host.

Structure and Metamorphism

The main foliation is defined by several location fabrics; namely, the gneissosity, quartz veining and country-rock schlieren. A weak shape-aggregate fabric in the quartzofeldspathic minerals parallels these. The boudinage is probably coeval with the foliation. These fabric elements are equivalent to the main foliation in the host paragneiss.

Earlier fabric elements are either primary or represented by the sheet and dykes themselves and also by the paragneiss schlieren. These tectonic elements are now parallel to the main foliation in the host paragneiss.

The main foliation and the dykes are warped and cut by shear zones, and folded into open to asymmetric structures. Static recrystallization also postdates the main foliation and accounts for the general lack of mineral fabrics in the rock (except for mimetic biotite in the schlieren). This recrystallization produced the polygonal texture in the felsic minerals and generated the biotite and orthopyroxene spotting; it relates to contact metamorphism by the Michikamau Intrusion (Unit 10).

Contact Relationships

The tonalitic rocks are intrusive into pelitic and psammitic paragneiss (subunits 5e and 5f) on Rusty Island in Fraser Lake, and have been thermally metamorphosed by the Michikamau Intrusion (Unit 10).

Inclusions (Unit 7) in the North Pole Brook Intrusive Suite (Unit 9)

Massive, foliated or layered, metamorphosed enclaves of granitoid, dioritic and amphibolitic rocks.

Definition and Division

Unit 7 is composed of large rafts and xenoliths enclosed in, and intruded by, granitoid rocks of the North Pole Brook Intrusive Suite (Unit 9). These inclusions are not typical of, and cannot be confidently assigned to, earlier units in the map area. Their distinctiveness is based on their lithology and structural and metamorphic states. The varied inclusion types are not subdivided.

Age

Most inclusions are known only to have a pre-Unit 9 (late Early Proterozoic) age. Some may have been affected by the same intense deformation and metamorphism that characterizes the Sail Lake intrusive suite (Unit 2); most appear to postdate, or be unaffected by, this event.

Distribution

The rafts occur in a lakeshore outcrop at the west end of the large island between Fremont and Mackenzie lakes, 10 km southwest of the Orma dyke; in two other lakeshore outcrops in the west of Windbound Lake near the centre of the southern map edge; and at a locality on the southern shore of an island, 10 km southwest of the west end of Mackenzie Lake.

Description

The enclaves include granitoid rocks, amphibolite and diorite. Granitoid rocks occur at all of the localities and are the only representative of the unit between Fremont and Mackenzie lakes and in the southwest of the map area. They are cream- or greenish-weathering, medium- to dark-grey, medium-grained, biotite-bearing quartzofeldspathic rocks in which the relative feldspar proportions are generally unknown. The granitoid rocks are foliated, posttectonically annealed and contain mimetic or random biotite porphyroblasts. Layered xenoliths and schlieren of mafic and felsic material, commonly exhibiting mafic cores and felsic rims, are enclosed in the granitoid enclaves in the Windbound Lake outcrops. The Windbound Lake granitoid enclaves also contain an ill-defined compositional streakiness along with rare, rodded, biotite-bearing granitoid rock (eastern outcrop) and rare inclusions of weakly foliated, magnetite-bearing tonalite or granodiorite (western outcrop). The layered xenoliths consist of amphibolite and predominate in the western outcrops at Windbound Lake. They consist of alternating anorthositic layers and mafic amphibolite layers, generally 1 to 20 cm in thickness. The layering is tightly folded in places. Some enclaves are a more homogeneous amphibolite and are intruded by fine-grained, grey diorite; both the amphibolite and the diorite are intruded by a dyke of hornblende-spotted leucodiorite. (The amphibolites are interpreted to be metagabbros.)

Southwest of the west end of Mackenzie Lake, the Unit 7 granitoid enclave occurs as a layered, foliated to weakly gneissic, tabular xenolith.

Irregular patches of ferromagnesian material with felsic haloes occur in a part of the granitoid raft between Fremont and Mackenzie lakes (Plate 37). The ferromagnesian patches

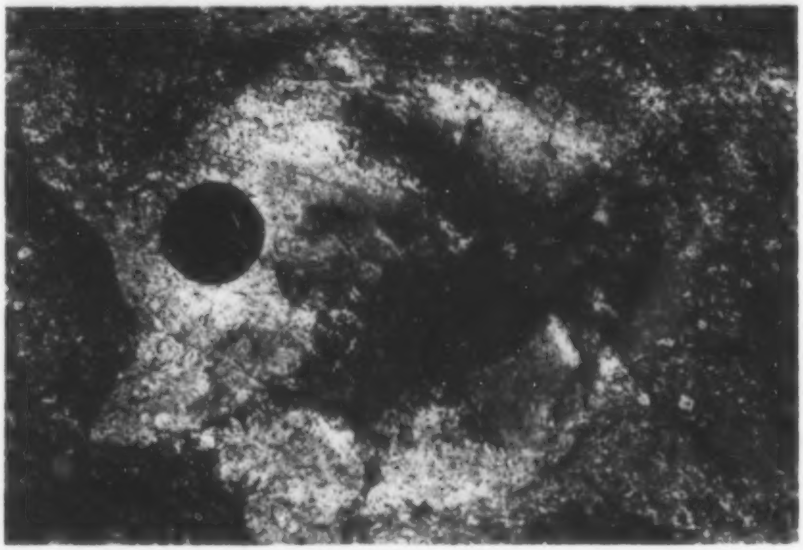


Plate 37. *Irregularly shaped nodular structure having a weathering-resistant halo (light coloured) in large raft of granite (Unit 7), which is an inclusion in the North Pole Brook Intrusive Suite (Unit 9). Photo GN81-CS24-32, locality G511, NTS 13L/3W, GR 8200.9135. Diameter of coin is 2.1 cm.*

consist of brown-weathering, recessive, hornblende-rich cores containing epidote and minor plagioclase. Some patches form rims around small xenoliths, others look like xenoliths. They are surrounded by a discontinuous hornblende–plagioclase rim, in which the proportion of plagioclase increases outward, followed by a ferromagnesian-depleted felsic halo in the granitoid host rock that is both deformation and weathering resistant. The haloes have very irregular scalloped (convex-inward) contacts with the ferromagnesian patches, and generally smoother, rounded to elliptical external shapes. The combined features range in size from 2 to 10 by 12 cm.

A foliation is defined by feldspar, quartz and ferromagnesian groundmass mineral fabrics, and by oriented plagioclase phenocrysts or their replacement aggregates. As well, a weak elongation of the resistant haloes in the first outcrop, and, in the Windbound Lake localities, similar groundmass mineral fabrics, a weak compositional variation, rare rodding, and flattened streaky xenoliths, enhance the foliation.

The shape of the raft between Fremont and Windbound lakes is unknown; it occurs on the south side of the outcrop and is at least 20 m across. All other enclaves are angular, equant to tabular blocks of largely random orientation, and vary in size from decimetres to greater than 1 by 10 m. They are commonly clustered as an agmatite.

The foliated and/or annealed biotite porphyroblastic granitoid rocks may be precursors of the North Pole Brook Intrusive Suite (Unit 9) that have been recrystallized by inclusion in the voluminous later phases of the batholith. However, they might equally range back to the Sail Lake intrusive suite (Unit 2) in age, and their foliation and recrystallization may also be older than the Labradorian events associated with the batholith. Many of the associated rock types have compositions and grain sizes compatible with subunits 1b or 3a/b (amphibolite) and Unit 2 (granitoid rocks), although, with the exception of the rodded granitoid rock, their strain states are lower than is typical of these rocks.

Petrography

The large raft between Fremont and Mackenzie lakes was originally plagioclase porphyritic. The plagioclase phenocrysts are now represented by recrystallized aggregates. The groundmass is also granoblastic and consists of quartz–microcline–plagioclase–biotite–hornblende–opaque minerals–epidote–allanite–chlorite–apatite. The biotite is green or greenish brown in both the groundmass and as porphyroblasts, and green hornblende, opaque mineral, epidote and allanite may also be porphyroblastic. Epidote and allanite commonly rim opaque minerals and chlorite is a later alteration product of the ferromagnesian minerals.

Structure and Metamorphism

All the inclusion types are foliated to some degree, although locally, amphibolite and the diorite are very weakly deformed or undeformed. The foliation is parallel to the layering in the amphibolite and in the streaky mafic–felsic xenoliths or schlieren, and in the case of the latter, this orientation is parallel to the foliation in the enclosing Unit 7 granitoid rock. These foliations do not occur in the North Pole Brook Intrusive Suite (Unit 9) host rock or dykes, and are now variably oriented.

The amphibolite contains a layering (primary?) that predates the foliation. The granitoid rocks are posttectonically recrystallized and annealed and locally contain fresh, black biotite porphyroblasts. (These features may be due to contact metamorphism by the Unit 9 host.) Later still, chlorite alteration and epidote- and quartz-mineralized joints occur in most areas, in both the inclusions and their host rocks.

Contact Relationships

At each locality, the enclaves are intruded by medium- to coarse-grained, commonly K-feldspar-megacrystic granitoid rocks of the North Pole Brook Intrusive Suite (Unit

9). These occur as dykes and net-veins, or as the host to individual inclusions and agmatitic groups of xenoliths. Relationships to other units are unknown.

LATE PROTEROZOIC I

Mackenzie Lake Group (Unit 8)

Andesitic volcanic rocks and arenaceous metasedimentary rocks.

Definition and Division

Rocks defined here as the Mackenzie Lake group (Unit 8) were first mapped on the prominent hill west of Mackenzie Lake and included in a group of 'chiefly mafic and intermediate volcanic rocks' (Emslie, 1964b). Further investigation of the same hill added acidic volcanic rocks to the succession (Emslie, *in* Wanless and Loveridge, 1978, pages 45, 46), which Emslie (1978a) then separated from the largely mafic volcanic rocks, as an upper Petscapiskau Group. Mapping of the areas to both the northwest of the west end and the northeast of the east end of Mackenzie Lake added clastic sedimentary rocks (Nunn and Noel, 1982).

Following reservation of the term Petscapiskau Group for Emslie's (1978a) lower Petscapiskau Group (Nunn and Noel, 1982; Nunn and Wardle, 1985), Emslie's upper Petscapiskau designation was dropped and the rocks renamed the Mackenzie Lake group (Nunn *et al.*, 1985).

The group is defined as being composed of supracrustal rocks that predate the Trans-Labrador batholith (North Pole Brook Intrusive Suite, Unit 9) and the Michikamau Intrusion (Unit 10) but that lack pre-existing regional metamorphic fabrics (in contrast to the Petscapiskau Group, Unit 5 and the Archean supracrustal rocks, Unit 1). The supracrustal rocks are separated into volcanic and metasedimentary subunits, and these are further subdivided according to field appearance and geographic area, respectively.

Unit 8 occurs in the southwest of the map area, in the southeast of the map area between Fremont and Marie lakes, and in the centre of the map area in the south of Vollant Lake.

Age

Emslie (1964b) assigned the volcanic rocks to the middle of three sedimentary packages that were defined during his original mapping. Following a rubidium–strontium whole-rock age determination on the acidic volcanic rocks west of Mackenzie Lake (subdivision 8a^4) that gave an isochron (recalculated) of 1525 ± 60 Ma (Wanless and Loveridge, 1978, pages 45-46), these rocks were defined as the type locality of a Paleohelikian upper Petscapiskau Group (Emslie, 1978a,c).

Krogh (1985) reported a uranium–lead discordia determination from the andesitic porphyry west of Mackenzie Lake (subdivision 8a^1) that gave an upper intercept of 1651 ± 3 Ma (Appendix 1). The abundant examples of intrusive relationships of the North Pole Brook Intrusive Suite (Unit 9) into the volcanic rocks (subunit 8a), and available isotopic data indicating a ca. 1576 Ma and/or 1654 Ma age for the Trans-Labrador batholith (Nunn *et al.*, 1985), of which the North Pole Brook Intrusive Suite is a part, suggest that the older date of Krogh is more realistic (Figure 7).

Subunit 8a

Andesitic, quartz andesitic and minor dacitic volcanic rocks.

Distribution and Subdivision

The volcanic rocks underlie the two larger outcrop areas, the islands and most of the shoreline outcrops in the southwest of the map area, and also occur as enclaves in the Vollant Lake area. The largest outcrop area is an approximately 3.5 by 2 km, northerly elongated, ovoid area 5 km west of Mackenzie Lake. The next largest area is a 1.5 by 1 km, easterly elongated, rectangular area 10 km northwest of the west end of Mackenzie Lake. Both of these areas underlie prominent hills. Eight kilometres southwest of the west end of Mackenzie Lake, the subunit occurs on four small islands and one larger island 300 m in diameter. A farther 2 km southwest and 4 km west, there are a number of shoreline outcrops on the southwestern sides of the larger islands in Michikamau Lake. The enclaves occur at four localities in the south of Vollant Lake.

Subunit 8a is the volcanic subunit of the Mackenzie Lake group. It was divided into five subdivisions in the field on the basis of general petrological characteristics, some of which correspond to minor compositional differences.

Subdivision 8a^1 occurs as an east-northeasterly trending, 400-m-wide, 1-km-long ridge and peninsula at the southern margin of the largest outcrop area. Subdivision 8a^2 occupies two thirds of the largest outcrop area in two strips separated by a north-northwesterly oriented layer of 8a^4. It also forms the whole of the second largest area and the shoreline outcrops on the southeastern of the two larger islands near the edge of Michikamau Lake. Subdivision 8a^3 occupies the cluster of four small islands 8 km southwest of the west end of Mackenzie Lake, the shoreline outcrop on Low's Island (the northwestern of the two larger islands near the edge of Michikamau Lake), and enclaves in Vollant Lake. Subdivision 8a^4 occurs as a 0.75-km-wide, 2.5-km-long layer oriented in a north-northwesterly direction in the largest outcrop area west of Mackenzie Lake. Subdivision 8a^5 underlies the larger island 8 km southwest of the west end of Mackenzie Lake.

Description

Subdivision 8a^1 is a medium- to light-grey- or pinkish-weathering, dark-grey, massive, homogeneous andesitic porphyry (Plate 38). It forms well-jointed, grey craggy

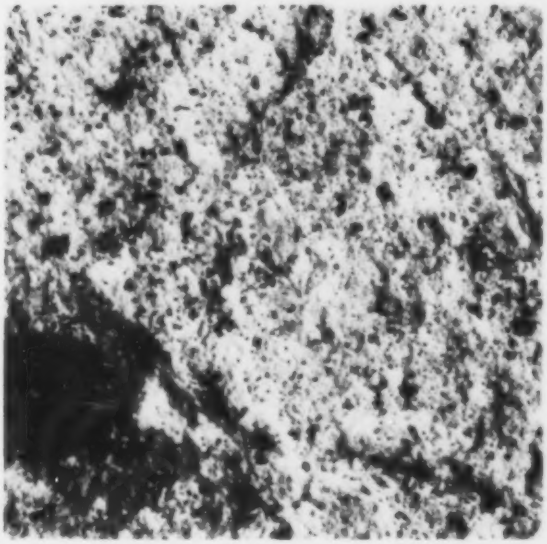


Plate 38. *Plagioclase- and altered-pyroxene-porphyritic, hypabyssal andesite (subdivision 8a^{1}). Photo GN81-CS30-9, locality G598a, NTS 13L/4W, GR 4840.9225. Diameter of coin is 1.85 cm.*

outcrops in contrast to the more rounded granitoid outcrops (Unit 9) in the area. Fresh surfaces mostly appear uniformly medium grained; however, weathered surfaces indicate approximately 50 percent medium- to coarse-grained plagioclase phenocrysts and 10 to 15 percent medium-grained ferromagnesian phenocrysts in a fine-grained light-grey-weathering groundmass (Plate 38). The plagioclase phenocrysts are euhedral to subhedral, equant to elongated (laths with aspect ratios of 3 or 4:1) and up to 1 cm across. They are randomly oriented and evenly distributed throughout the rock, and are either dark-grey- and recessive-weathering or white-weathering. The black ferromagnesian phenocrysts are also evenly distributed. Also scattered evenly throughout the rock are angular, felsic fragments of similar size to the phenocrysts (broken phenocrysts?). On pink-weathering outcrop surfaces and joint faces in the wave-washed exposures along the shoreline, the dark phenocrysts are obscured and the rock appears to consist of white plagioclase phenocrysts in a pink groundmass. This weathering-induced appearance makes the rocks look superficially similar to the plagioclase-porphyritic quartz monzonite (subunit 9c), which is abundant in the area.

Greenschist-facies alteration is abundant and manifested by epidotization, plagioclase saussuritization and hematite staining. The first two are particularly common along the northern shoreline of the peninsula and result in large patches of greenish rock, locally containing smaller patches of the much-less-altered normal grey facies.

Subdivision 8a^{1} is probably a hypabyssal rock. It is not in exposed contact with the other subdivisions in subunit 8a. However, it is included within subunit 8a on the basis of spatial association, plagioclase-phenocryst contents, mineralogical composition, and a similar grey colour and craggy-outcrop appearance to subdivision 8a^{2}. Along the north shore of the peninsula, the rock is intruded by microgranite (subunit 9h), diabase (subunit 12a) and plagioclase-megacrystic diabase (subunit 12b).

Subdivision 8a^{2} comprises light- to dark-grey-weathering porphyritic andesite containing pinkish alteration zones. Fresh surfaces are dark grey or grey-green and locally plagioclase phenocrysts stand out as white spots. The rocks consist of a fine-grained (rarely fine to medium grained and seriate textured) groundmass containing plagioclase and ferromagnesian phenocrysts of variable proportions, size and development. The groundmass consists of plagioclase and mafic minerals $\leq$ 0.5 mm in size. Plagioclase phenocrysts predominate. They range in proportion and size from a few tiny ($\leq$ 0.5 mm) crystals to profuse (40 to 60 percent) equant, stumpy or elongated (aspect ratios of 3 to 6:1), subhedral to euhedral laths that are 1 to 5 mm long. Ferromagnesian phenocrysts usually make up 10 to 15 percent of the rock and consist of black pyroxene, black or dark-green hornblende and hornblende pseudomorphs after pyroxene; they are 1 to 3 mm long and have a stumpy lath-like shape. Biotite occurs in places. Ferromagnesian phenocrysts are locally absent in the plagioclase-phenocryst-rich facies, but pyroxene or hornblende, and biotite(?) also form the mafic phenocrysts in a microporphyritic phase (see below). Magnetite occurs, rarely, as large rounded to oval grains and may also be a phenocryst phase.

Three facies are defined for the subdivision, based primarily on the plagioclase phenocrysts. In the most common facies, plagioclase phenocrysts form 10 to 30 percent of the rock (normal andesite). A second facies consists of the plagioclase-phenocryst-rich rock, and the third facies is microporphyritic such that phenocrysts of 1 mm or less occur in an aphanitic groundmass. Most outcrops or groups of outcrop consist of one facies or another. However, in several outcrops occurring on the large hill west of Mackenzie Lake, both the normal and microporphyritic facies were found intermixed, although no relationship was determined between them. One microporphyritic locality in the same area was almost entirely aphanitic. Phenocrysts are usually randomly oriented and evenly distributed; however, another microporphyritic locality was mapped, in which the mafic phenocrysts are aligned, but in many directions within the outcrop.

In the northern outcrop area of subdivision 8a^{2}, the andesite is much less homogeneous (Plate 39). In places, the rock contains numerous patches of coarser grained crystallization. The smaller patches are more or less rounded, whereas the larger ones (up to 8 cm long) are irregular. Most of the patches comprise hornblende-dominated hornblende–plagioclase ± epidote assemblages. Hornblende forms black, equant laths up to 7 mm across. Some of the patches possess a mineral zoning composed of an approximately 1-cm-thick, black hornblende rim passing inward to either green amphibole (actinolite?) ± plagioclase ± quartz ± epidote,

Plate 39. *Discontinuous layers crowed with plagioclase laths in andesite (subdivision* $8a^2$*) containing patches of coarse crystallization that mimetically overprint an earlier planar feature (foliation(?)). Photo GN81-CS31-29, locality G483d, NTS 13L/4W, GR 4535.0088. Length of hammer is 34 cm.*

or amphibole followed by epidote only. Locally, the minerals in the patches have crystallized in a radial pattern. Rarely, the patches have a felsic halo around the hornblende rim; commonly, the patches weather in raised relief and locally they appear aligned (Plate 39). Black hornblende is also scattered throughout the andesite between the patches, either as clots up to 3 mm across or as small, subrounded grains and laths exhibiting rounded corners (poikiloblasts). Both the patches of coarser grain size and the scattered black hornblende in this area are regarded as secondary (see subunit 8a, structure and metamorphism). The phenocrysts in this andesite consist of the usual plagioclase and rare, dark-green, 1- to 2-mm-hornblende laths. Locally, plagioclase laths are aligned in discontinuous, irregularly shaped layers (Plate 39) or occur as glomeroporphyritic or stellate clusters.

Several of the shoreline localities in the northern outcrop area contain a granular, sugary groundmass that appears to be composed of quartz as well as feldspar, and this rock may be transitional into subdivision $8a^4$. Plagioclase, hornblende and minor biotite are the phenocryst phases.

The aligned plagioclase-porphyritic layers and the variably oriented, lineated ferromagnesian microphenocryts are probably primary structures. The apparent alignment of some coarsely crystalline patches in the north may be mimetic.

Fractures, quartz veins and epidote- and quartz-mineralized joints occur, mostly in the northern outcrop area. Pinkish alteration zones are common in association with these features.

Homogeneous, dark-grey, fine-grained, irregular, glassy dykes intrude the porphyritic andesite at a locality near the western contact of the $8a^4$ subdivision layer.

Subdivision $8a^3$ is a dark-green- to grey-weathering, fine- to very-fine-grained, plagioclase-rich andesitic rock. Fresh surfaces are dark grey or dark green. The groundmass commonly appears aphanitic but locally contains plagioclase laths and needles (up to 0.5 mm in length) and green hornblende. Mostly, the andesite is plagioclase or plagioclase + hornblende porphyritic (Plate 40); rarely, it contains only hornblende, pyroxene or biotite phenocrysts. Plagioclase phenocrysts are equant to stumpy, euhedral, randomly oriented, up to 8 mm across, and commonly saussuritized. Porphyritic hornblende occurs as stumpy laths up to 3 mm long and pyroxene phenocrysts form equant, subrounded crystals up to 6 mm across.

Locally, subdivision $8a^3$ is weakly layered, contains coarser grained felsic patches with scattered hornblende crystals, or contains felsic vein systems. The felsic vein systems vary from a close-spaced, narrow, streaky plagioclase location fabric to random or net-vein systems of granitic to trondhjemitic material that locally is graphic or pegmatitic. Commonly, plagioclase in these veins is saussuritized and the veins are pale green. Epidote alteration is abundant. The vein systems predate dyke intrusion by, and inclusion in, the local granitoid rocks of the North Pole Brook Intrusive Suite (Unit 9), and at a locality in the south of Vollant Lake, net-veining predates a flattening and weak easterly trending foliation.

Several features occur adjacent to the contacts between the porphyritic andesite and Unit 9 granitoid rocks. At the shoreline outcrop on the south side of Low's Island in Michikamau Lake, a separate andesitic facies forms a 2-m-thick sheet between the quartz monzonite (subunit 9c) and plagioclase-porphyritic andesite. It consists of random plagioclase needles and laths, and intergranular to subophitic green hornblende. In addition, felsic segregations of quartz, quartz + K-feldspar, and quartz monzonite occur heterogeneously throughout the sheet; these range from individual 1 mm grains of quartz to patches up to 2 cm across. Both margins of the sheet are wavy but sharp. On one of the islands in the cluster 8 km southwest of the west end of Mackenzie Lake, the surrounding hornblende quartz monzonite (subunit 9c) has unusually high concentrations of hornblende immediately adjacent to xenoliths of andesite. At one place

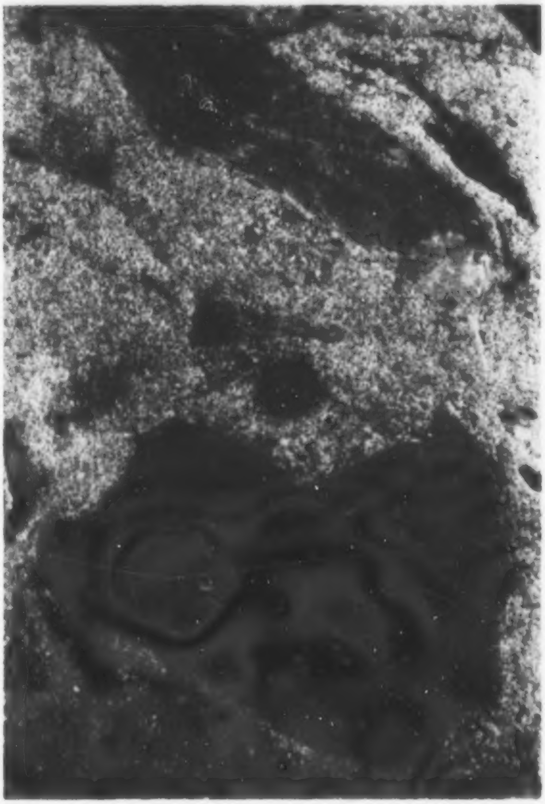


Plate 40. *Green-weathering porphyritic andesite (subdivision 8a^3, below) and layered metasedimentary hornfels (subdivision 8b^3, above) enclaves in quartz monzonite (subunit 9d). Photo and locality NN81-241, NTS 13L/3W, GR 7354.0345. Diameter of lens cap is 5.5 cm.*

in Vollant Lake, the quartz monzonite is chilled against large enclaves of andesite or metasedimentary rock. Examples of the enclaves are shown in Plate 40.

Typically, outcrops and enclaves of the andesite are cut by fractures and mineralized joints. They are generally multidirectional and range from few to numerous; less commonly, they define a location or fracture fabric. The joints and fractures commonly are mineralized—mostly by epidote, rarely by amphibole—and weathering-resistant plagioclase-alteration haloes about 1 mm wide are common on either side of the structure. On one of the islands in the cluster southwest of the west end of Mackenzie Lake, several sets of epidote-mineralized joints are specific to andesite enclaves, whereas several others continue into the host granitoid in which the haloes are pink instead of white or pale green.

Subdivision 8a^4 comprises grey- to green-weathering, dark-grey, siliceous, porphyritic, acidic volcanic rocks. Two main facies are present. One is a grey-weathering, weakly foliated, glassy, plagioclase- and quartz-porphyritic rock containing abundant quartz ocellae and small nodules. The other is a green-weathering, foliated, plagioclase ± quartz porphyritic rock. Both facies have fine grained matrices. The relationship between the two is unknown.

In the weakly foliated facies, coarsely to finely crystalline milky-quartz ocellae and nodules are up to 8 cm across. The largest nodules are round but most are elliptical to broadly polygonal and some of the latter have rounded 'corners'. Smaller ocellae (≤ 6 mm) are rounded or elliptical, some may have pyramidal terminations and some occur as black 'eyes'. Plagioclase phenocrysts are euhedral to subhedral, stumpy to elongate laths (0.3 to 3 mm across and 1 to 5 mm long), and range from a minor component to about 20 percent of the rock. There are rare occurrences of poikilitic biotite clots composed of an isotropic mesh of very fine-grained, fresh black biotite containing numerous tiny quartz and feldspar inclusions, and amphibole–quartz patches and elliptical clasts composed of a fine-grained, felted mesh of green amphibole needles. The clasts are enveloped by a 3 to 10 mm wide, black biotite reaction rim that is thickest in the clast strain shadows, where it 'feathers' into the surrounding rock in a direction parallel to a weak phenocryst alignment and groundmass foliation.

In the foliated facies, a streaky, anastomosing foliation and dark schlieren warp around aligned or random, stumpy plagioclase laths (2 to 5 mm long), and the foliated groundmass contains abundant chlorite and quartz. Plagioclase phenocrysts make up approximately 40 percent of the rock, and 2- to 3-mm-quartz ocellae, together with minor, small (≤ 1 mm) quartz euhedra ± hornblende phenocrysts, are also present. Abundant greenish mafic clots and quartz lenticles, patches and veins also occur, along with rare, irregular, quartz–actinolite patches surrounded by quartz haloes, and quartz–amphibole–epidote veins. Locally, homogeneous, fine-grained layers make up a part of this facies.

Subdivision 8a^5 is a coarsely porphyritic andesite. It is cream- to green-weathering and dark-grey-green on fresh surfaces. Phenocryst phases consist of 30 to 40 percent plagioclase and minor hornblende. The plagioclase phenocrysts come in varying shapes and sizes up to 1.2 cm across. The larger ones are equant or stumpy (aspect rations ≤ 5:2) and locally glomeroporphyritic; they seem isotropically distributed. Medium-sized plagioclase phenocrysts are equant to elongated (≤ 4:1), 1 to 6 mm long and commonly define a mineral fabric. The groundmass is fine grained.

Many outcrops are riddled with fractures, which commonly include epidote mineralization and plagioclase-alteration haloes. Rarely, zones of epidotization are up to 0.5 m across.

In places, the rock has two weathering facies; more resistant or less resistant: locally, the less resistant occurs in layered or dyke-like form. No difference was noted between the two facies except for more prevalent fracturing in the more resistant rock.

Petrography

In subdivision 8a^1, plagioclase phenocrysts contain combinations of simple, lamellar and interpenetrant twins, are generally zoned throughout and, locally, are packed together in hypidiomorphic patches. Saussuritization of plagioclase phenocrysts is well developed where present, but varies from localized patches in the crystal to almost complete replacement. Some of the plagioclase phenocrysts have thin, untwinned, less saussuritized albite rims, which may extend as overgrowths into felsic-dominated groundmass containing plagioclase and minor microcline. The presence of minor K-feldspar gives an andesitic, trending toward trachyandesitic, composition to this rock. The ferromagnesian phenocrysts consist of clinopyroxene that is commonly twinned or zoned and contains opaque exsolution lamellae parallel to the twinning. Clinopyroxene is commonly rimmed by brown biotite or partially replaced by aggregates of biotite + opaque mineral ± green hornblende ± apatite. Locally, ragged clots of epidote + opaque mineral + green hornblende completely replace the pyroxene phenocrysts. Epidote is common as subhedral to globular grains and as amorphous patches replacing or rimming ferromagnesian minerals. The rock also contains apatite, zircon and titanite(?).

In an example of the microporphyritic phase of subdivision 8a^2, hornblende phenocrysts are equant to stumpy and up to 1.1 mm long. The phenocrysts commonly are zoned. Others contain cores of an anhedral hornblende aggregate (recrystallization) enclosed in an optically continuous narrow rim that defines either a euhedral to subhedral shape or, very rarely, a synneusis aggregate. Although of overall definite shape, the margins of the phenocrysts are very ragged in detail and the rims appear to have crystallized simultaneously with the groundmass. Small ocellae, of equivalent to to up to three times phenocryst size, are present, establishing a common feature with subdivision 8a^4 (see below). The ocellae are composed of quartz + hornblende ± opaque mineral ± epidote. The groundmass consists of plagioclase and hornblende laths, 0.25 mm or less in size, and minor epidote, rare biotite and opaque minerals. The groundmass plagioclase and hornblende define a mineral fabric that wraps around the phenocrysts, many of which are also aligned.

In the northern outcrop area of subdivision 8a^2 to the northwest of Mackenzie Lake, heterogeneity in the rock is due to the variable presence of phenocrysts, poikiloblasts and patches of coarse-grained crystallization. The phenocrysts consist of plagioclase (which may be weakly aligned) and aggregates of hornblende–opaque mineral ± biotite, which are probably pseudomorphs after pyroxene; the poikiloblasts are green hornblende. Locally, the coarse-grained patches contain quartz, graphic-looking quartz–plagioclase intergrowths, opaque minerals, carbonate and a zeolite-like mineral, in addition to the minerals noted in hand specimen (hornblende, plagioclase, epidote and amphibole). The opaque mineral occurs as scattered, fine-grained, granular crystals in hornblende near the outer margins of the patches, and the carbonate–zeolite assemblage is always the last, intergranular or intersertal crystallization. Some patches have a narrow rim against, or in, the enclosing rock of equant, felted, orange-brown biotite containing a colourless, fibrous, cleavage-parallel alteration product. The groundmass to all these features consists of fine grained (≤ 0.35 mm) saussuritized plagioclase, hornblende, biotite, epidote and opaque minerals. With the exception of the phenocrysts at a few localities, all the rock elements are isotropically distributed and the groundmass includes stellate hornblende and saccharoidal textures. Locally, hornblende is partially recrystallized in the coarse-grained patches.

In the southeastern part of this outcrop area, hornblende crystallization has not occurred and the phenocryst phases include clinopyroxene, plagioclase, an opaque mineral, orthopyroxene and biotite. The plagioclase phenocrysts have lamellar-twinned cores, narrow untwinned overgrowths, and random, untwinned recrystallized patches. The recrystallization commonly eradicates the saussuritization of the feldspar and is associated with granular epidote crystallization. Biotite phenocrysts are very ragged and commonly contain an internal spotting, also of biotite. Biotite commonly rims opaque minerals. The groundmass is composed mostly of plagioclase, which occurs either as anhedral plates containing numerous internal plagioclase spots or as a recrystallized, anhedral, granular aggregate containing minor epidote, biotite, opaque minerals and pyroxene(?).

A microporphyritic rock from the northern outcrop area of subdivision 8a^2 has undergone extensive recrystallization forming hornblende. The ferromagnesian (pyroxene?) phenocrysts have been replaced by shapeless clots of either green hornblende or pale hornblende. Euhedral–subhedral porphyroblastic hornblende is also present. These features occur in a groundmass of plagioclase, hornblende, biotite, quartz, opaque minerals and, locally, microcline, and accessory apatite. The plagioclase commonly exhibits a mineral fabric. The biotite is olive green to khaki and is partly altered to a colourless, fibrous mineral. The quartz ± microcline occurs in groundmass patches as large monzonitic plates enclosing plagioclase, biotite and rare hornblende. (This texture is also seen in subdivision 8a^5.)

Most rocks of subdivision 8a^2 lack significant quartz and K-feldspar and are andesites. Locally, quartz is present in ocellae and in coarsely crystalline patches related to metamorphism; in these cases, it has not been included in the compositional determination. The microporphyritic phase from the northern area of subdivision 8a^2 contains quartz and microcline in the groundmass and trends from andesite toward a dacitic composition.

In subdivision 8a^3, phenocrysts, mostly plagioclase, form 20 to 30 percent of the rock. Biotite and clinopyroxene–opaque mineral intergrowths also occur as phenocryst phases, but most ferromagnesian phenocrysts have been replaced by poikiloblastic clots of hornblende ± biotite + an opaque mineral ± titanite ± quartz. The phenocrysts are enclosed in a plagioclase-dominated groundmass that includes hornblende or clinopyroxene + orthopyroxene (± thin clinopyroxene rims), and opaque minerals + biotite ± titanite

± apatite. Apatite commonly forms abundant, random, small, thin needles in the plagioclase. Groundmass plagioclase exhibits a well-developed mineral fabric that either wraps around the phenocrysts or is enclosed in the poikiloblasts. Quartz occurs as anhedral to polygonal patches in the groundmass and in veins associated with hornblende. These rocks are andesite or quartz andesite.

In Vollant Lake, the rock is andesite and is hornblende- and minor plagioclase-porphyritic and flow-aligned or foliated. The groundmass consists of aligned plagioclase, hornblende, an opaque mineral and biotite. The aligned plagioclase laths exhibit albite, carlsbad albite and simple twins parallel to their elongation.

In subdivision $8a^4$, the feldspar phenocrysts generally form moderately elongate laths and are simply, and usually only singly, twinned. They are thought to be mostly plagioclase but microcline and antiperthite also occur. Feldspar phenocrysts are locally corroded by the groundmass, have commonly developed subgrains or are partly recrystallized, and are variably saussuritized or studded with coarser grained reaction products such as epidote, hornblende, opaque minerals and titanite(?). Ferromagnesian phenocrysts are not present in this subdivision. However, porphyroblastic crystals and clots of hornblende (± epidote rims) and biotite, and, less commonly, quartz, an opaque mineral, titanite and biotite–titanite–epidote, or epidote–hematite occur along with poikiloblastic or stellate clusters of epidote and titanite. Quartz and quartz-rich ocellae are common. Minerals associated with these nodules, but generally minor or accessory in proportion, include hornblende, plagioclase, green to brown biotite, titanite, muscovite, zircon, allanite and opaque minerals. Quartz in the ocellae is recrystallized to fine-grained anhedral to polygonal aggregates containing grains 0.01 to 0.4 mm in diameter. The groundmass is composed of plagioclase, quartz, hornblende, epidote, opaque minerals, titanite and, rarely, muscovite and apatite. Much crystallization is isotropically oriented; locally, feldspar phenocrysts and feldspar, biotite and epidote groundmass minerals define the foliation.

A glassy, felsic dyke contains strongly saussuritized, euhedral feldspar phenocrysts and pervasively, but less strongly, altered xenocrysts or xenoliths of feldspar. The precise precursor of the latter is unknown because they are generally round or irregular and represented by subgrains or aggregates of recrystallized grains. These inclusions are rimmed by a zone of variable thickness of olive-green biotite + an opaque mineral + scattered epidote, and are up to 5 mm across. The groundmass is equigranular, mostly 0.02–0.04 mm (up to 0.1 mm) in grain size, and composed of the assemblage quartz–feldspar–biotite–epidote–opaque minerals–apatite.

The abundance of quartz and the minor occurrence of K-feldspar in this subdivision indicates a quartz andesite to dacitic composition.

Subdivision $8a^5$ consists of abundant plagioclase and minor biotite phenocrysts in a groundmass of plagioclase + clinopyroxene + quartz + biotite + hornblende + opaque minerals. Poikiloblastic patches of hornblende, rarely having cores of clinopyroxene, are up to 1.5 mm in diameter. Both the clinopyroxene and the quartz in the groundmass range from intersertal grains to ophitic plates moulded on plagioclase. This rock is a quartz andesite.

Structure and Metamorphism

The volcanic rocks mostly are massive and lacking in regional foliations. An approximately layer-parallel or northerly trending, anastomosing, greenschist-facies foliation occurs in the dominantly plagioclase-porphyritic facies of subdivision $8a^4$ and similarly oriented, narrow leucocratic segregations occur in an outcrop of subdivision $8a^3$. An easterly trending foliation affects enclaves and net-veins in Vollant Lake. Other alignments and layering are probably primary.

Much of the veining and leucocratic segregations, present in subunit 8a, appears to be related to the emplacement of granitoid rocks of the North Pole Brook Intrusive Suite (Unit 9). Abundant fracturing, veining and greenschist-facies mineralization of fractures and alteration are present that both pre- and postdate intrusion of the granitoid rocks. Locally, net-veins predate foliation development.

The coarse-grained patches and the non-phenocryst hornblende grains and clots in the northern outcrop area probably also are posttectonic with respect to the foliation. The patches are randomly distributed and their occurrence in the northern area only, plus their proximity to the Michikamau Intrusion (Unit 10), indicate that they formed in the contact aureole of the intrusion. Stellate and sugary groundmass textures, internal spotting in minerals, and the isotropic subgrain or replacement textures of phenocrysts and inclusions are all most probably related to thermal metamorphism by either the North Pole Brook Intrusive Suite (Unit 9) or the Michikamau Intrusion (Unit 10). The coarse-grained stellate plagioclase clusters may be porphyroblastic rather than glomeroporphyritic.

Contact Relationships

Andesite (subdivision $8a^2$) and quartz andesite and dacite (subdivision $8a^4$) are interlayered as part of a volcanic sequence. Hypabyssal andesite (subdivision $8a^1$), andesite and quartz andesite (subdivision $8a^3$), and plagioclase-porphyritic quartz andesite (subdivision $8a^5$) do not occur in contact with any of the other subdivisions. Subunit 8a volcanic rocks are not in contact with the clastic rocks of subunit 8b or earlier units, but are intruded in many places by granitoid rocks (North Pole Brook Intrusive Suite, Unit 9) and diabase dykes (Unit 12). The hypabyssal andesite (subdivision $8a^1$) contains dykes of microgranite, diabase and plagioclase-megacrystic diabase (subunits 9h, 12a and 12b, respectively). Andesite of subdivision $8a^2$ is intruded by plagioclase-porphyritic quartz monzonite (subunit 9c) and microgranite (subunit 9h). The spatial relationships of the coarse-grained patches in the northern outcrop area of andesite (subdivision $8a^2$) with the rest of the subdivision and with the Michikamau Intrusion (Unit 10) imply that it is also earlier than, and contact metamorphosed by, the intrusion. Andesite and quartz andesite (subdivision $8a^3$) form enclaves in, or are intruded by dykes of, quartz monzodiorite (subunit 9b/f), plagioclase-porphyritic quartz monzonite (subunit 9c), quartz monzonite (subunit 9d, Plate 40), microgranite (subunit 9h) and diabase (subunit 12a).

Subunit 8b

Red and grey, arenaceous and minor calcsilicate hornfels.

Distribution and Subdivision

Subdivision $8b^1$ forms two large lakeshore outcrops 8 km west-northwest of the west end of Mackenzie Lake in the southwest of the map area (Map 93-19). It also occurs as inclusions in the Michikamau Intrusion (Unit 10) on the shores of Windy Bay. Subdivision $8b^2$ is located between Fremont and Marie lakes in the southeast of the map area. Subdivision $8b^3$ occurs as enclaves in the south of Vollant Lake in the centre of the map area.

Description

In the west (subdivision $8b^1$), the easternmost of the two outcrops consists of pink-, greyish- and orange-weathering, grey, medium- to coarse-grained, crossbedded feldspathic arenite. The crossbedding occurs on two scales: discontinuous, lenticular, 5- to 30-cm-thick layers of foresets form the smaller scale truncations; these are grouped together in cosets of from 0.4 to 1 m thickness. The cosets are tabular and continuous over the outcrop length of 12 to 14 m. Both foreset and coset truncation surfaces are low angle. The foresets consist of 1-mm to 2-cm laminae and rare, thicker 3- to 5-cm layers, and are accentuated by weathering-induced colour banding of pale (white to pink) and greyish layers. Grey, fresh surfaces look homogeneous and recrystallized. Weathered surfaces reveal random needles or plates of a ferromagnesian mineral (biotite; see petrography).

The western outcrop consists of an interbedded sequence of coarser and finer grained groups of layers (Plate 41). Relative percentages of coarse and fine layers are very variable; either group may be dominant resulting in a cyclicity on many scales from about 20 cm up. Intermediate grain-size layers and laminae are common, approximately 0.5 cm thick, locally exhibit a very flat lenticularity, and occur scattered throughout both coarse- and fine-dominated cycles. Also scattered throughout the sequence are 10- to 30-cm, westward-fining rhythms. All layers are parallel laminated, plane sided and tabular, and almost all appear continuous across the outcrop strike length of approximately 18 m. On fresh surfaces, the rocks are dark grey and have a recrystallized appearance.

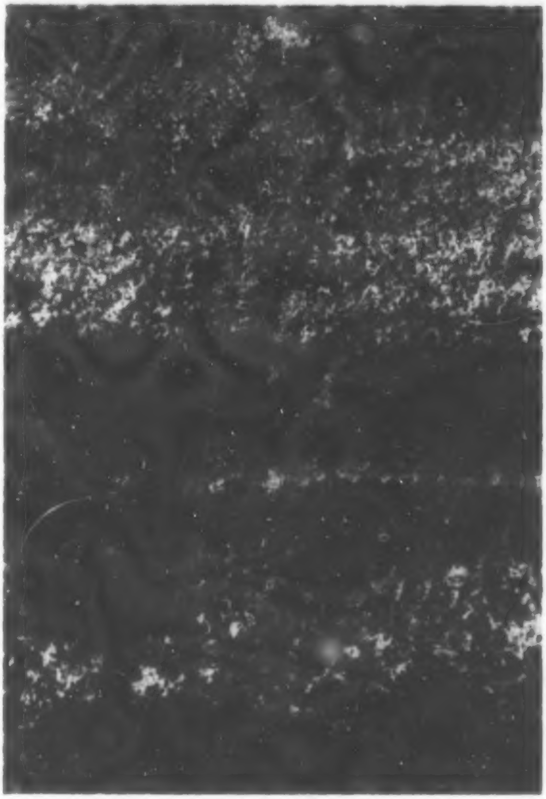


Plate 41. *Graded metasedimentary hornfels (subdivision $8b^1$). Photo GN81-CS27-31, locality G580e, NTS 13L/4W, GR4675.9728. Diameter of coin is 2.1 cm.*

Coarser grained beds are white-weathering and generally 1 to 4 cm thick (some are up to 20 cm thick). They are fine to medium grained (1 to 3 mm), and some exhibit a weak grading, fining to the west (Plate 41). The rock has a large matrix component. Coarser grains consist of feldspar, quartz and ferromagnesian porphyroblasts, and recessive-weathering brown patches. Some brown patches were originally euhedral to subhedral, equant to rectangular and 1 to 2.5 mm across; these are now recrystallized clots including finely granular magnetite. Other patches consists of less regular forms and a greater size range (0.5 to 3 mm) and are less magnetic. Finer grained beds are grey-weathering and mostly 1 to 10 cm thick, but locally are up to 20 cm thick. They are fine to very fine grained ($\leq$ 0.5 mm) and spotted with magnetic grains (0.5 to 1.5 mm) that have felsic haloes. Internal laminae of slightly different grain sizes are more common in the finer layers than in the coarser ones.

On the shore of Windy Bay, inclusions of grey, light-grey-weathering, fine-grained, layered feldspathic rock are enclosed in a marginal phase of the Michikamau Intrusion (Unit 10). The inclusions are folded and contain dark magnetic spots and felsic segregations. The dark spots are up to 4 mm across, commonly have felsic haloes and occur in a fine-grained matrix of 0.5 mm or less. In the western outcrop of subdivision $8b^1$, 7 km to the southeast, rocks similar to these inclusions contain ferromagnesian porphyroblasts of pyroxene + an opaque mineral (presumably magnetite); therefore, these inclusions are correlated with subunit 8b.

The segregations in the inclusions are medium- to coarse-grained feldspathic veins, patches and lines of patches. They consist of plagioclase ± pyroxene ± quartz ± magnetite and occur as random, straight or mimetic features. Some segregations mimetically accentuate folded layering. The inclusions are metasedimentary hornfels and the layering is a relict bedding. They are intruded by dykes, veins and net-veins of gabbroic or troctolitic rocks.

Between Fremont and Marie lakes (subdivision $8b^2$), the rocks are composed of moderately to indistinctly layered or massive, pinkish-brown- to grey-weathering arenite. Layers are tabular with plane or undulose sides and are decimetres to metres thick. Internal structures were not noted; however, locally, thin calc-silicate layers occur between some of the thinner bedded parts of the sequence. The arenite is subarkosic to arkosic. Locally, at least, it exhibits a strong granular recrystallization; the thin, originally muddy, layers have recrystallized to amphibolite. The presence of garnet and diopside in these layers suggests that they are lime rich.

In the Vollant Lake area, enclaves of metasedimentary rocks (subdivision $8b^3$) are randomly oriented in a quartz monzonite (subunit 9d) where they are intermixed with inclusions of andesite (subdivision $8a^3$). The metasedimentary inclusions are layered and arenaceous but possibly also include tuffaceous or fragmental rock. They are light-grey to grey-green weathering and darker on fresh surfaces. Some inclusions are weakly foliated parallel to the layering.

Petrography

In the eastern outcrop of subdivision $8b^1$, the random ferromagnesian needles or laths are sections across plates of porphyroblastic biotite up to 2 mm across. Less commonly, biotite forms similar-sized isotropically textured clots. Other porphyroblasts include 0.1- to 0.35-mm, zoned, ragged-edged subhedra of plagioclase, scattered opaque grains approximately 1 mm across, and poikiloblastic clots of clinopyroxene ± coarser-than-groundmass plagioclase and an abundant fine-grained opaque mineral. The clinopyroxene-bearing clots contain no biotite and commonly have a ferromagnesian-depleted quartz−plagioclase halo. Rare, irregular patches of quartz up to 1 mm across are also present. The matrix is composed of 0.01- to 0.03-mm, subequant, polygonal quartz + plagioclase ± biotite ± opaque mineral. The rock has a spotted hornfels texture.

The western outcrop of subdivision $8b^1$ is also a spotted hornfels: the grain size and rhythmic variations are due to changes in the size and abundance of the feldspar porphyroblasts and may reflect compositional rather than grain size grading. The coarser spotted layers contain 50 to 75 percent, 1 to 3 mm, euhedral to subhedral, sieved plagioclase porphyroblasts. These grains are zoned, simply or lamellar twinned, selectively saussuritized and divided into subgrains, and contain 0.15 to 0.5 mm inclusions. Ferromagnesian spots form about 10 percent of the rock. The magnetite porphyroblasts commonly have biotite rims. The less magnetic patches consist of either biotite ± an opaque mineral, or green hornblende, or clinopyroxene ± hornblende rims. The groundmass consists of 15 to 40 percent of the rock; quartz becomes increasingly dominant over plagioclase as the percentage of matrix decreases. The matrix mostly consists of 0.01- to 0.05-mm, polygonal, equant to lath-like plagioclase and quartz with biotite + opaque minerals + epidote + clinopyroxene ± green hornblende ± titanite ± apatite. Layering also occurs due to variations in the biotite content and the presence of clinopyroxene or hornblende.

Individual layers in subdivision $8b^2$ exhibit a wide range in composition but predominantly are arkosic. Plagioclase, microcline or quartz all exceed 50 percent of the modal composition in different layers, and either plagioclase or microcline commonly is absent. The ferromagnesian minerals consist of green hornblende, olive-green or brown biotite, clinopyroxene, opaque minerals, titanite and minor epidote, muscovite, chlorite and zircon, any of which is locally absent.

Texturally, the rocks are hornfels and the minerals are generally evenly distributed and finely granular. Clinopyroxene, hornblende and plagioclase are either porphyroblastic or poikiloblastic in part. The clinopyroxene is replaced by, or occurs as cores to, the hornblende in some layers. Titanite is anhedral and moulded on other minerals, such as plagioclase or clinopyroxene, and locally it, with or without epidote, rims or replaces hornblende and opaque minerals. More rarely, muscovite, an opaque phase and epidote are poikiloblastic and biotite occurs as clots ± hornblende having opaque mineral rims. Various combinations of plagioclase, muscovite, biotite, opaque minerals and chlorite locally form a spotting, commonly exhibiting quartz or quartz−plagioclase haloes. Plagioclase porphyroblasts commonly exhibit subgrains or are recrystallized to anhedral aggregates. The fine-grained, granular, granoblastic groundmass locally contains patches of coarser grains.

The arenaceous or tuffaceous metasedimentary rock from subdivision $8b^3$ in Vollant Lake contains the assemblage quartz−microcline−plagioclase−biotite−opaque mineral−titanite−epidote−apatite−zircon. The ferromagnesian minerals occur in disseminated biotite−opaque mineral−titanite ± apatite clots or patches; apatite-rich lenticles are present also. Epidote rarely rims an opaque mineral and the zircons are very small. The rock has a metamorphic texture and is characterized by either very fine-grained, rounded, spotty inclusions or recrystallized grains enclosed in coarser granoblastic minerals.

Structure and Metamorphism

Tectonic fabrics are either absent or weak in the metasedimentary hornfels; some may have been destroyed by the recrystallization. Folding in the enclaves in the

Michikamau Intrusion (Unit 10) may be a relict regional structure or may be due to plastic deformation of hot inclusions during emplacement of the intrusion. All rocks are recrystallized with isotropic textures and occur in the pyroxene- or hornblende-hornfels facies.

Contact Relationships

The clastic metasedimentary hornfels has no known relationship to older units or directly to the volcanic rocks of the unit (subunit 8a). However, xenoliths of andesite (subdivision $8a^3$) and metasedimentary hornfels (subdivision $8b^3$) are intermixed in a North Pole Brook Intrusive Suite quartz monzonite host (Unit 9) in the south of Vollant Lake. The metasedimentary hornfels is intruded by dykes of granitoid rock (Unit 9) and occurs as xenoliths near the contacts in the southeast of the map area and at the first western outcrop. No relationship exists at the second western outcrop; however, all three outcrops, together with that in Vollant Lake, have been isotropically recrystallized and this is thought to be the result of thermal metamorphism by the North Pole Brook Intrusive Suite. Subdivision $8b^1$ occurs as enclaves in the marginal zone of the Michikamau Intrusion (subdivision $10a^2$), 300 m from the contact with the country rock, in Windy Bay. Subdivision $8b^2$ forms a roof pendant in North Pole Brook Intrusive Suite quartz monzonite (subunit 9d).

North Pole Brook Intrusive Suite (Unit 9)

Massive to foliated, commonly K-feldspar-megacrystic, granitoid rocks and minor gabbro, anorthosite and diorite, and granitic minor intrusions.

Definition and Division

Rocks included here in the North Pole Brook Intrusive Suite (Unit 9) occupy approximately 50 percent of the southern half of the map area and form a large (55 by 27 km), roughly semicircular lobe in the south-central part of the map area and a subsidiary, approximately 9 by 6 km area in the southeast of the map area. These rocks were described as 'Massive granitic rocks, typically medium to coarse grained, pink; chiefly biotite-bearing ....' by Emslie (1964b), and are continuous with similar rocks to the south and southeast (Nunn, 1981, 1982; Wardle and Britton, 1981; Wardle, 1985; Thomas, 1981; Thomas and Hibbs, 1980). To the south, the granitoid rocks have been termed the Michikamau Pluton (Wardle, 1985); to the southeast they form the North Pole Brook Intrusive Suite (Thomas and Hibbs, 1980; Thomas, 1981). Regionally, the granitoid rocks are part of the 700-km-long Trans-Labrador batholith that occurs at the northern edge of the Labrador Orogen (Thomas *et al.*, 1985, 1986; Thomas, 1993) within the northern part of the Grenville Province (Wardle *et al.*, 1986).

Regionally, the batholith is in intrusive or tectonic contact with older units to the north, most of which have undergone polydeformational regional metamorphism at upper greenschist or higher grades (e.g., the Petscapiskau Group, Unit 5), and is unconformably overlain by red-bed sequences that predate the Grenville Orogeny (e.g., the Seal Lake Group, Unit 11). In the map area, the batholith and the red-bed cover rocks are simply (non-penetratively) deformed under greenschist-facies conditions or less. The North Pole Brook Intrusive Suite (Unit 9) is thus defined in the map area as a granitoid-dominated plutonic suite that postdates orogenesis in older rock types (Units 1 to 6) and predates regional red-bed deposition (Unit 11).

The North Pole Brook Intrusive Suite is a composite of mainly granitoid rock types, but includes minor gabbro and diorite (Nunn and Noel, 1982). The granitoid rock types are dominated by K-feldspar-megacrystic varieties. The suite is divided into subunits, primarily on the basis of composition and partly on textural or chronological grounds.

Age

Dates on the North Pole Brook Intrusive Suite (Figure 7) consist of a K–Ar date of 1403 ± 77 Ma on biotite (Lowden *et al.*, 1963, page 116) and a U–Pb date of 1576 ± 10 Ma on zircon (Brooks, 1983; Appendix 1). Both come from the main K-feldspar-megacrystic members of the suite. The K–Ar date is regarded as a disturbed number reflecting a mixing effect of the Grenville Orogeny on the cooling of the North Pole Brook Intrusive Suite. The U–Pb date may represent the crystallization age of some of the suite in this area.

Regionally, many dates indicate an age of 1655 to 1650 Ma for most of the batholith (Figure 8; Krogh, 1983; Nunn *et al.*, 1985). The age of the unit is further constrained between U–Pb zircon dates of 1651 ± 3 Ma on a cover sequence that it intrudes (Krogh, 1985; see Unit 8), and 1327 ± 4 Ma on felsic volcanic rocks (Letitia Lake Group) that unconformably overlie a part of the batholith 40 km east of the map area (Figure 8; Fryer, 1983).

Subunit 9a

Hydrous gabbro and minor anorthosite.

Distribution

The subunit occurs as a 0.5 by 2 km, easterly oriented area on the north side of an island in the string of islands between Mackenzie and Windbound lakes in the southeastern part of the map area, and underlies several smaller islands immediately to the north. It also underlies a triangular-shaped, 0.7 by 1.5 km island between Fremont and Mackenzie lakes near the southeast-centre of the map area, and occurs as equant and elongate patches up to 1 km long on the large island that separates Vollant Lake from the westerly extension of Orma Lake, also near the south-centre of the map area.

Description

Subunit 9a is the gabbroid part of the North Pole Brook Intrusive Suite and consists of hornblende gabbro and leucogabbro, two-pyroxene hornblende gabbro and minor anorthosite.

Between Mackenzie and Windbound lakes, the subunit is green-weathering, black or dark grey-green and white-mottled, fine- to medium-grained hornblende gabbro and leucogabbro. The colour index ranges from 25 to 45 and is defined by hornblende, minor biotite and rare titanite. Hornblende commonly forms 0.5- to 1.0-cm-diameter poikiloblastic grains enclosing plagioclase; the poikiloblasts commonly weather recessively to give a pitted outcrop surface. Some poikiloblasts are zoned and contain deeper green rims around pale-green or brownish cores; they may represent amphibole replacement of subophitic pyroxene. Biotite alteration along amphibole cleavage is present, particularly in poikiloblast cores. Groundmass hornblende is black, fine grained and intergranular to plagioclase phenocrysts along with quartz, plagioclase and rare allanite. Plagioclase phenocrysts are euhedral, white-weathering, grey and medium grained and rarely contain small inclusions. The quartz content is generally 2 to 5 percent, but locally reaches 10 percent.

Locally, the rock is heterogeneous and indistinct patches (possibly several different phases) of varying colour index occur. Xenoliths are common (up to 20 percent of the rock); most are small, fine-grained, dark-coloured, angular to ovoid forms composed of hornblende and lesser, commonly porphyritic, plagioclase. One to four millimetre hornblende-spotted (approximately 5 percent) leucogabbro, and epidotized xenoliths are also present. Xenoliths locally have 1 to 6 mm thick, darker or lighter reaction rims, where they are in contact with the host gabbro; in places, the host contains a non-porphyritic, more felsic (than the normal gabbro) chilled margin along its contact with the xenoliths. Fine-grained leucogabbro (a colour index of 10 to 15) dykes also occur at one locality, and granitic, aplitic and pegmatitic veins (subunit 9h) are scattered throughout.

The gabbroic rocks are undeformed except along their southern margin; however, some leucogabbro xenoliths are foliated, some leucogabbro dykes are folded, and locally, the gabbro contains a wavy felsic-veinlet fabric. Epidote- and amphibole-mineralized fractures are common, some of which exhibit depletion of mafic components adjacent to the fractures.

Quartz gabbro from less than 200 m south of the map boundary in an adjacent map area is almost identical to that between Mackenzie and Windbound lakes (Plate 42).

Between Mackenzie and Fremont lakes, greenish-weathering, rarely brown-spotted, dark-grey, medium- to coarse-grained pyroxene-bearing hydrous gabbro underlies most of the triangular island. Plagioclase either forms equant to elongated (aspect ratio ≤ 4:1) laths up to 1 cm across or is replaced by aggregates preserving an euhedral shape, and locally defines an igneous lamination. Hypersthene occurs as smaller, subequant, dark-honey-brown to dark-grey-brown phenocrysts, and is also present in the groundmass. Hornblende forms poikiloblastic grains up to 3 cm across (generally 1 to 2 cm) and possibly replaces ophitic pyroxene in places. The groundmass is composed of greenish clinopyroxene and/or calcic amphibole, intergranular plates of hypersthene, and minor biotite and plagioclase. The rock is undeformed but contains amphibole-, hornblende-, or hornblende–amphibole–plagioclase-mineralized fractures. Graphic granite dykes (subunit 9h) are also present.

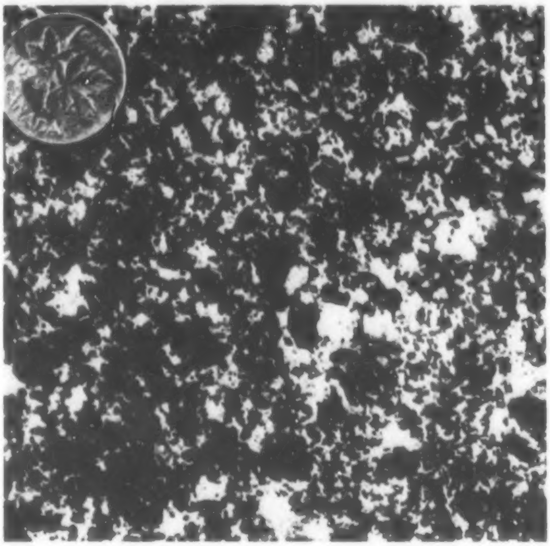


Plate 42. *Plagioclase- and hornblende-porphyritic quartz gabbro (subunit 9a). Photo GN81-CS24-2, locality G490c (180 m south of map edge), NTS 13E/14W, GR 7380.8322. Diameter of coin is 1.85 cm.*

South of Vollant Lake, the subunit consists of massive, blocky-weathering, dark-grey, fine-grained biotite anorthosite, medium-grained leucogabbro and a metamorphic-textured leucoamphibolite. The anorthosite contains abundant fractures, parallel felsic veinlets and granitoid dykes.

Structure and Metamorphism

Subunit 9a is undeformed texturally, except in a foliated zone containing abundant elongated xenoliths along the southern margin of the area between Mackenzie and Windbound lakes. However, some deformation of the subunit is indicated by folded leucogabbro dykes in the same area, and by a synformal disposition to the plagioclase lamination on the island between Mackenzie and Fremont lakes (two measurements only).

Earlier structural features are confined to rare foliated xenoliths, and later ones to vein and fracture sets.

The hornblende and amphibole replacement of pyroxene, biotite alteration of hornblende, and mineralization of the joints and fractures are static. They may be related to either late magmatic activity or low-grade regional metamorphism.

Contact Relationships

The southern contact of the area between the Mackenzie and Windbound lakes is a foliated zone containing abundant, relatively large xenoliths, south of which the rocks consist of quartz diorite (subunit 9b). The change appears to be gradational, but an originally sharper contact may have been obscured in this zone. Between Vollant and Orma lakes, the anorthositic rocks occur as enclaves in, and are intruded by dykes of, megacrystic granitoid rocks of subunit 9d and probably contain a sheet of quartz monzonite; all areas are cut by granitic dykes and veins (subunit 9h).

Subunit 9b

Quartz diorite and minor diorite, quartz monzodiorite and tonalite.

Distribution

The subunit forms a triangular area (Map 93-19), south of subunit 9a on the island between Mackenzie and Windbound lakes. Outcrop distribution suggests a 7 by 2 km northwesterly elongated body (mostly covered by water) in the east of Vollant Lake. Other areas consist of scattered outcrops and small areas west and southwest of Vollant Lake, in the southwestern corner of the map area near Michikamau Lake, and in the east between Fremont and Marie lakes.

Description

Subunit 9b is a group of granitoid rocks of dioritic affinity that is dominated by biotite–hornblende quartz diorite, but also includes minor diorite, quartz monzodiorite and tonalite.

The quartz diorite is a massive, dark-speckled, white- to cream-weathering, grey rock (Plate 43). Locally, pink alteration zones and stained joint faces are common. Most localities are medium to coarse grained but finer grained varieties occur in many areas, in particular, between Mackenzie and Windbound lakes. The colour index ranges from 10 to 40, hornblende is approximately equal to, to very much greater than, biotite. Magnetite is common but minor, except near Marie Lake where magnetite and biotite are abundant and hornblende is absent. Quartz is generally about 10 percent but ranges from less than 5 percent to greater than 20 percent. Most feldspar is white or pale-green saussuritized plagioclase in a grey to pink groundmass. Grey, porphyritic, K-feldspar ranges up to approximately 10 percent in places, but is generally much less.

For the most part, the rock is densely porphyritic with a fine- to medium-grained groundmass (Plate 43). The phenocrysts consist of equant to stumpy laths of plagioclase up to 1 cm across, hornblende up to 6 mm long, and plates of biotite up to 6 mm across. Generally, however, these minerals form 3 to 4 mm phenocrysts. In places, ferromagnesian phenocrysts are replaced by amphiboles with brownish or green cores and black rims; these may originally have been pyroxenes. Rarely, K-feldspar forms up to several percent of anhedral, grey, zoned megacrysts that are up to 1.5 cm across. The large K-feldspars contain small plagioclase inclusions. The groundmass is composed of smaller hornblende and biotite laths moulded on small, early plagioclase laths, together with intergranular magnetite and anhedral quartz and K-feldspar.

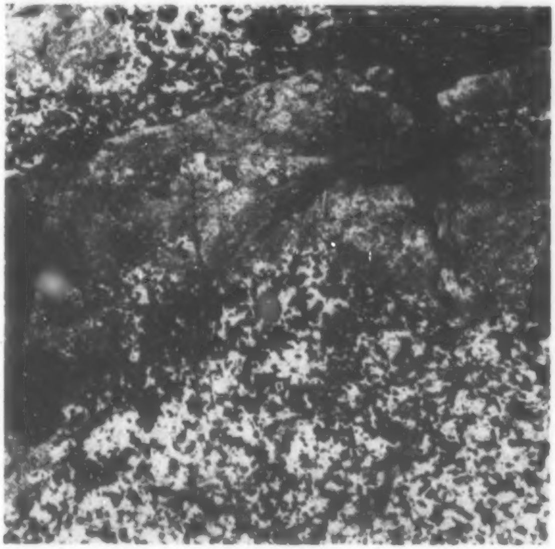


Plate 43. *Mafic dyke (subunit 12a), containing xenocrysts and small xenoliths of its host, intruding quartz diorite (subunit 9b/f). Photo and locality NN81-184, NTS 13L/4E, GR 6442.0515. Width of the dyke is about 15 cm.*

The names given to the rocks within the subunit vary due to continuous and gradual variations in composition, mostly in terms of quartz and K-feldspar contents. Texturally, the dioritic rocks are relatively homogeneous.

Xenoliths are ubiquitous throughout subunits 9b to 9f inclusive, and range locally from abundant to rare. Cognate-looking xenoliths ranging from dioritic to monzonitic to granodioritic are most common. Most are mesocratic and darker than their host but range from leucocratic to melanocratic. They are fine to medium grained (invariably finer grained than their host), equant to flattened, mostly oval to tabular, and small (commonly < 10 cm, rarely > 25 cm, and a few are up to several metres long). Textures range from uniform to inequigranular; the latter includes seriate, porphyritic, porphyroblastic (± haloes) and xenocrystic textures. Coarser grained minerals consist of one or combinations of plagioclase, hornblende, biotite, magnetite and K-feldspar, to which quartz and polycrystalline quartzofeldspathic aggregates can be added in xenocrystic varieties. Margins range from sharp to diffuse and locally are rheomorphic or outlined by mafic or felsic selvages. Rarely, xenoliths have finer grained margins adjacent to the host granitoid rock, and these, together with the xenocrystic varieties, probably represent disrupted dykes or immiscible fluids. Other xenolith types are rare and include amphibolite, granite and aplite.

Large enclaves of andesite (subdivision $8a^3$) and metasedimentary hornfels (subdivision $8b^3$) occur in subunit 9b/f in the south of Vollant Lake. The former are grey to green, commonly green weathering, fine grained and locally plagioclase and/or ferromagnesian porphyritic. Some contain felsic net-veins, epidote or amphibole veinlets, or a fracture fabric. The metasedimentary enclaves are grey, fine grained and contain a streaky fabric parallel to a weak compositional layering.

Many localities contain granitoid dykes; a few are fine- to medium-grained quartz diorite or quartz monzodiorite, most are seriate-textured aplite to pegmatite granites (subunit 9h). Rarely, irregular diabase dykes (subunit 12a) are also present (Plate 43).

Epidote and quartz–epidote veinlets, as well as epidote-mineralized joints and fractures, are widespread. Saussuritization of plagioclase phenocrysts and chloritization of ferromagnesian minerals, especially adjacent to the mineralized fractures, are also common.

Locally, the quartz dioritic rocks are foliated. The foliation normally occurs as small shear zones or as a ferromagnesian mineral fabric. Near Marie Lake, some magnetite-rich zones contain oriented magnetite.

Structure and Metamorphism

The dioritic rocks are rarely foliated. However, ferromagnesian or magnetite mineral fabrics and small shear zones are present locally. Xenoliths are commonly flattened or oval and are either elongated parallel to the foliation or are elongated without any other fabric elements present. Amphibole and epidote mineralization of fractures, the saussuritization of plagioclase, alteration of hornblende to biotite or chlorite, and of biotite to chlorite, may be products of late magmatic alteration. Conversely, later, low-grade, regional metamorphism may have caused the alteration.

Contact Relationships

Dykes of quartz monzodiorite intrude the porphyritic volcanic rocks (subdivision $8a^2$) at one locality in the southwest of the map area. Two phases of quartz diorite make up the dykes, one with a colour index of about 10, the other with a colour index of 15 to 20. Enclaves of andesite (subdivision $8a^3$) and metasedimentary hornfels (subdivision $8b^3$) occur in quartz monzodiorite of subunit 9b/f on islands in the south of Vollant Lake. The relationship between quartz diorite (subunit 9b) and gabbro (subunit 9a) on the island between Mackenzie and Windbound lakes is uncertain (see subunit 9a above). Relationships between quartz diorite to quartz monzodiorite (subunit 9b) and quartz monzonite (subunit 9d) were not observed within the map area but are well known from the area to the south (Nunn, 1981), where quartz monzonite dykes intrude and include the quartz dioritic rocks at most contacts. The dioritic rocks are intruded by dykes of similar composition, granitic dykes (subunit 9h) and diabase dykes (subunit 12a, Plate 43) within the map area.

Subunit 9c

Plagioclase-porphyritic quartz monzodiorite to quartz monzonite.

Distribution

Subunit 9c predominantly occurs in the southwest of the map area where it underlies the islands between Michikamau and Agnes lakes, and lakeshore areas farther north (a largely water-covered area of approximately 150 km^2). It also occurs as small patches and isolated outcrops in, south and north of Vollant Lake in the centre of the map area, and south of Marie Lake in the southeast of the map area.

Description

Subunit 9c is massive, buff-, grey- and pink-weathering, grey, medium- to coarse-grained quartz monzodiorite to quartz monzonite. The rock is characterized by white porphyritic plagioclase in a grey to pink anhedral groundmass (Plate 44). Plagioclase phenocrysts are commonly saussuritized and pale green. They occur as equant to stumpy, random and rarely aligned laths up to 1 cm across, but mostly 3 to 6 mm in diameter. Grey, zoned K-feldspar phenocrysts (mostly 1 to 2 cm in diameter but up to 3 cm) contain small, euhedral plagioclase inclusions, locally have white (albite?) rims, rarely appear perthitic, and generally form 5 to 8 percent, and up to 15 percent, of the rock. The phenocrysts have irregular margins that merge into pink groundmass plates of K-feldspar or aggregates of K-feldspar and quartz. Phenocrystic K-feldspar is subordinate to groundmass K-feldspar in this subunit. Grey, and less commonly blue, quartz

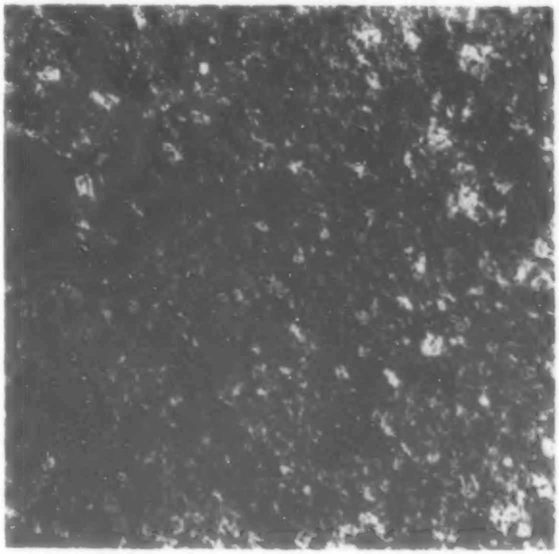


Plate 44. *Plagioclase- and hornblende-porphyritic quartz monzonite (subunit 9c) – note white plagioclase phenocrysts surrounded by (pink) K-feldspar + quartz groundmass. Photo GN81-CS27-33, locality G580f, NTS 13L/4W, GR 4682.9734. Diameter of coin is 2.1 cm.*

occurs only in the groundmass, usually in anhedral aggregates with K-feldspar and forms 10 to 15 percent of the rock. In some places, quartz corrodes the plagioclase phenocrysts.

Hornblende and biotite also form phenocryst phases. Hornblende is greater to very much greater than biotite in concentration, and, with magnetite, defines a colour index of 5 to 10 associated with rarer more leucocratic phases. These minerals also occur with plagioclase in the groundmass, in hypidiomorphic aggregates or as needles. Locally, biotite is chloritized and hornblende replaced by blue-green (actinolitic?) amphibole. Quartz–K-feldspar groundmass aggregates are more resistant to weathering than plagioclase–ferromagnesian ± quartz aggregates. Groundmass grain sizes are mostly 1 to 3 mm in diameter.

Xenoliths are abundant in the quartz monzodiorite to quartz monzonite, particularly in the southwest of the map area. Most are finer grained dioritic types of very variable colour index and grain size, and exhibit uniform to porphyritic and porphyroblastic textures. They are irregular to ovoid in shape and have fairly sharp margins; most are 4 to 8 cm in size but some are up to 60 cm across. One locality contains a large tabular xenolith of strongly foliated granitoid rock (Unit 7).

Dykes and veins of plagioclase ± hornblende-porphyritic microgranite and aplite, granite, graphic granite and pegmatite (subunit 9h) are common. Diabase dykes (subunit 12a) are rare.

The rocks are rarely foliated. Usually the foliation takes the form of a plagioclase-phenocryst and ovoid-xenolith alignment in an apparently undeformed, anhedral, igneous groundmass. In places (e.g., south of Marie Lake), the foliation is more penetrative and round-cornered plagioclase phenocrysts occur in a groundmass exhibiting a fracture cleavage or containing a quartz or ferromagnesian grain elongation.

Wide zones of pink-weathering, outcrop-surface or joint-face alteration occur and seem spatially related to more abundant epidote mineralization and veining. The subunit is also quartz veined; locally, these veins are related to intense shearing and are mylonitic.

Petrography

Plagioclase phenocrysts are usually zoned and the zoning is commonly paralleled by variations in the degree of saussuritization, generally with the cores more heavily affected. Although their general form is euhedral to subhedral, in detail they vary from euhedral to irregular (it is not known whether the latter is due to interference by overlapping groundmass crystallization or to groundmass corrosion or both). In a dyke cutting the raft of Unit 7 between Fremont and Mackenzie lakes, some plagioclase phenocrysts occur in glomeroporphyritic clusters of two or three laths; very rare synneusis pairs are also present. In this dyke, hornblende is absent and the groundmass consists of an anhedral mixture of K-feldspar and quartz along with biotite, epidote and an opaque mineral.

Structure and Metamorphism

The plagioclase-phenocryst and ovoid-xenolith alignment may be primary (or induced during cooling). Zones of stronger deformation are mostly subparallel to this alignment. Later structures include the epidote and quartz veining. The timing of saussuritization of plagioclase and alteration of ferromagnesian minerals is uncertain.

Contact Relationships

The quartz monzodiorite to quartz monzonite occurs as abundant dykes in, and contains enclaves of, both the metasedimentary and volcanic subunits of Unit 8 in the southwest of the map area. It also forms a few dykes that cut arkose (subunit 4a) in the southeast of the map area south of Marie Lake. Subunit 9c probably occurs as a sheet in anorthosite (subunit 9a) south of Vollant Lake. The plagioclase-porphyritic quartz monzodiorite to quartz monzonite is gradational in composition and texture into quartz diorite to quartz monzonite (subunit 9b), although a gradation into small patches similar to subunit 9b was only observed at one locality. Subunit 9c is also gradational into K-feldspar-megacrystic quartz monzonite (subunit 9d), particularly at the east end of the southeastern of the two large islands that occur 10 km southwest of the west end of Mackenzie Lake. Throughout the subunit, there are granitic and diabase dykes (subunits 9h and 12a) and an unconformable relationship is presumed for subdivision 11b^4 of Unit 11 (see below).

Subunit 9d

K-feldspar-megacrystic quartz monzonite to monzogranite.

Distribution

Subunit 9d is the most voluminous phase of the North Pole Brook Intrusive Suite in the map area. It occupies most of the southern, central and eastern parts of the main Unit 9 outcrop area, the southern and western parts of the subsidiary area to the north of Marie Lake, and all of the satellite plutons around the south of Kasheshibaw Lake and near Desolation Lake. The subunit is also intermixed with other subunits toward the west and on the north and northwest of the main Unit 9 outcrop area.

Description

Subunit 9d comprises massive, pink- to grey- and less commonly buff-weathering, dark-grey, medium- to coarse-grained, K-feldspar-megacrystic quartz monzonite or monzogranite (Plate 45). The K-feldspar megacrysts are dark grey, purple or pinkish, and usually 0.5 to 3 cm across. They

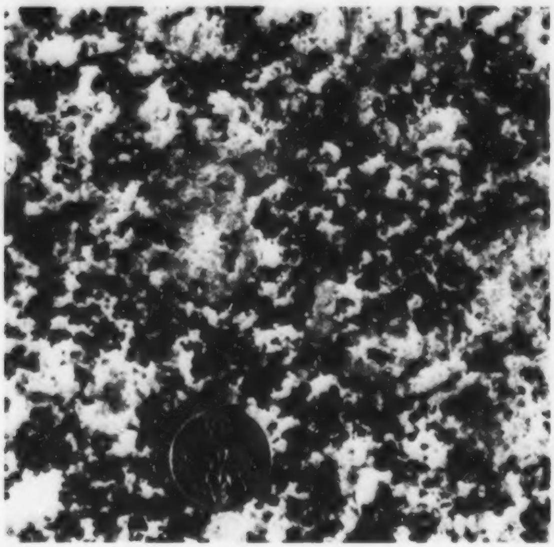


Plate 45. *K-feldspar-megacrystic monzogranite (subunit 9d). Photo GN81-CS27-5, locality G547a, NTS 13L/6W, GR 7801.1377. Diameter of coin is 1.85 cm.*

have a zoned, generally euhedral to subhedral shape, and contain small euhedral inclusions of plagioclase. Megacrysts occur up to 7 cm across and the larger ones are perthitic. Some megacrysts are more irregular and have pink overgrowths, which are locally continuous into groundmass plates of K-feldspar, and, rarely, rapakivi-type white-plagioclase rims. The K-feldspar megacrysts vary from abundant to sparse, but megacrysts usually dominate; megacryst and groundmass K-feldspar make up more than 25 percent of the rock.

Plagioclase forms euhedral, stumpy to rectangular phenocrysts that are mostly 0.5 to 1 cm in length and rarely up to 2 cm. The larger ones generally have ragged edges. Biotite and/or hornblende occur as 3- to 7-mm-diameter phenocrysts, and in groundmass aggregates with plagioclase and magnetite. Biotite is generally equal to or more abundant than hornblende. Titanite and allanite are common accessory minerals. The dark minerals define a colour index that is normally between 5 and 15, but darker and lighter phases occur. The remainder of the groundmass consists of anhedral plates of either quartz or K-feldspar, or anhedral to sugary aggregates of these same minerals. Groundmass grain sizes generally range from 2 to 6 mm in diameter, of which the quartz and K-feldspar mostly form the larger size fraction.

Possibly cognate, dioritic to more granitic xenoliths show the same types and variations as those in subunit 9c, although exotic xenoliths are more varied (Units 1, 2, 7 and 8). Granitic dykes (subunit 9h) are ubiquitous and diabase dykes (subunit 12a) are rare.

Foliated rocks are common in the subunit. They range from rocks exhibiting an alignment of plagioclase phenocrysts ± K-feldspar megacrysts and xenoliths, to rocks with a penetrative mineral fabric. The alignment most commonly occurs as a steep to vertical, approximately north-northeasterly orientation; the mineral fabric forms an anastomosing, approximately easterly oriented, moderately to steeply dipping foliation that is interpreted to wrap around large, kilometre-scale augen. Intermediate varieties of fabric type and orientation also occur. Chloritized biotite and hornblende, saussuritized plagioclase, and epidote and quartz-mineralized veins and fractures are common in association with the foliations. Some quartz and epidote veins are folded and contain mineral fabrics parallel to the host-rock foliation.

The quartz monzonite includes several unusual features 2.5 km north of the east end of the Fremont dykes in the river bed (now mainly dry) between Orma and Marie lakes. The main phase is fairly typical coarse-grained, igneous-textured quartz monzonite with a quartz content of less than or equal to 10 percent. K-feldspar megacrysts are equant, subhedral and 0.5 to 1.5 cm diameter, or elongated (aspect ratios of 2 or 3:1), euhedral and up to 2 cm long. Plagioclase is predominantly porphyritic and smaller than the K-feldspar megacrysts (generally 3 to 8 mm). Biotite forms porphyritic (plates up to 4 mm) and groundmass phases; it also occurs in clots, and commonly is associated with magnetite octahedra up to 1 mm across. Quartz and K-feldspar are associated in the groundmass. The megacrysts occur with tiny, euhedral plagioclase inclusions, ± thin plagioclase rims and ± pedicles continuous into groundmass feldspar. Biotite and magnetite define a usual colour index of 5 to 8; where biotite is minor or absent, its place is commonly taken by titanite. The titanite is red-brown weathering, euhedral or intergranular to plagioclase, and forms 2 to 5 percent (locally, in patches and layers, up to 10 percent) of the rock. (Titanite is a characteristic of the main phases of the Trans-Labrador batholith in central Labrador (Nunn and Christopher, 1983), but is rarely found in these concentrations.)

Atypically, parts of the quartz monzonite are layered. The layering is a combined grain size and compositional feature, and is composed of generally diffuse 2- to 33-cm-wide layers of medium-grained quartz monzonite containing proportionally fewer K-feldspar megacrysts than the coarser grained host quartz monzonite. The thinner layers are discontinuous, wavy to slightly anastomosing, and commonly bifurcate in a common direction. Rarely, they are asymmetric and contain one sharp contact and one gradational contact; titanite may be concentrated in the coarser grained host at the sharper contact.

Two suites of granitic dykes and sheets are present in these outcrops. The earlier suite consists of medium-grained, plagioclase- and K-feldspar-porphyritic granitoid rocks that contain a predominantly anhedral groundmass, and fine-grained, minor plagioclase-porphyritic granitoid rocks that are commonly seriate-textured and contain a mainly aplitic groundmass. The K-feldspar phenocrysts are more apparent on weathered surfaces, where they are pink, than on fresher surfaces, where they are grey; the plagioclase is white. Both phases of the earlier suite are more quartz rich than the host quartz monzonite, contain rare tonalitic and dioritic xenoliths (which are not found in their host), and lack chilled margins. The fine-grained phase of this earlier suite is a younger set and, rarely, may follow the locus of the older medium grained set of dykes. The younger set displays a mixture of usual brittle features (e.g., sharp contacts, xenoliths and apophyses) and synplutonic characteristics (e.g., irregular, curvy margins, rheomorphic interaction with the host instead of chilled contacts, and zonal or scattered distribution of host-rock xenocrysts, although the last could be corroded phenocrysts). In addition, the younger set is either homogeneous or heterogeneous, and the latter may consist of seriate textures or a poorly defined gneissosity, each of which may replace the other along strike. The gneissosity is anastomosing and, in places, takes on sigmoidal shear-zone-like forms and is always subparallel to the dyke or sheet. The older set and the host quartz monzonite contain rare, granular-textured, quartz-rich segregations with similar forms.

The earlier suite, its internal foliations, and the finer grained layering in the host quartz monzonite are all subparallel and trend southeasterly. In places, these features are folded, and, locally, the elongated K-feldspar megacrysts or the older dyke set exhibit mineral fabrics that trend easterly.

The later suite intrudes both the earlier suite and the quartz monzonite. It consists of typical seriate-textured, peg-structured, granitic dykes and pegmatites (subunit 9h). Quartz-rich patches contain quartz moulded on euhedral feldspar. Late cavities or vugs in the pegmatites are filled with rosettes of bladed epidote.

Structure and Metamorphism

The main foliation is the easterly oriented mineral fabric that is interpreted to anastomose around the kilometre-scale augen. It is defined by a greenschist-facies mineralogy, e.g., feldspar–quartz–chlorite–epidote. The main foliation is generally more penetrative than the phenocryst and xenolith alignment that locally occurs within the augen.

The north-northeasterly trending phenocryst and xenolith alignment is an older structure that is locally present in the augen between the later foliation zones. Locally, it is folded and in places it is truncated by, or rotated into, the anastomosing zones. The older foliation maintains a mainly igneous texture, except where it is better developed and penetrative at greenschist grade.

Quartz monzonite occurs in a mylonite zone in the Naskaupi River between Orma and Marie lakes (5 km east of the Orma dyke). Several hundred metres to the west of the mylonite zone, typically, the quartz monzonite is weakly foliated. The foliation gradually changes orientation and intensifies and the rock becomes increasingly fine grained and platey (in an eastward direction along the north side of the river). The rock is intruded by quartzofeldspathic veins adjacent to the mylonite zone. Porphyroclastic textures are developed and then destroyed as the rock changes from igneous, through protomylonite, to mylonite. The mylonite zone is north-northwesterly trending, steeply west-southwest dipping and contains an approximately down-dip lineation. The mylonitized green quartz monzonite contains pink granite veins and white quartz segregations that are isoclinally interfolded and subsequently kink banded. The deformation and recrystallization took place under greenschist-facies conditions. The mylonite is of uncertain age.

Epidote and quartz veining both predate and postdate the two foliations in the quartz monzonite. Minor static greenschist-facies metamorphism marked by chloritization of ferromagnesian minerals and saussuritization of plagioclase is ubiquitous. It could have occurred at any time during, or throughout, the structural history of the subunit.

Contact Relationships

The quartz monzonite to monzogranite is interpreted to be in intrusive or structural contact with Archean supracrustal rocks (Unit 1) and the Sail Lake intrusive suite; locally, it contains enclaves of very similar rock types to parts of these units. The subunit is probably intrusive into anorthosite (subunit 3a) and, although the contact was not observed, it is interpreted to thermally metamorphose the greywacke (subunit 5d). Quartz monzonite to monzogranite also contains large enclaves of unknown affinity (Unit 7), andesite (subdivision $8a^3$) and metasedimentary rock (subdivision $8b^3$), and roof pendants of metasedimentary hornfels (subdivision $8b^2$). It is gradational into plagioclase-porphyritic quartz monzodiorite to quartz monzonite (subunit 9c) and quartz syenite to granite (subunit 9e), occurs as enclaves in subunit 9f quartz monzodiorite, and is cut by a host of granitic dykes and veins of subunit 9h. An unconformable relationship with Seal Lake Group red beds (Unit 11) is inferred for the map area because this can be demonstrated regionally and at several places immediately south of the map area (Nunn, 1982). The subunit is cut by diabase dykes (subunit 12a).

Subunit 9e

K-feldspar-megacrystic quartz syenite to granite.

Distribution

Megacrystic quartz syenite to granite principally occurs in the north-central, northwestern and western parts of the main Unit 9 outcrop area, where it is intermixed with megacrystic quartz monzonite to monzogranite (subunit 9d). The subunit also occurs scattered through subunit 9d as rare isolated outcrops and small patches.

Description

The subunit is massive, pink- to grey- or red-weathering, dark-grey, medium- to coarse-grained, K-feldspar-megacrystic quartz syenite or granite (e.g., Plate 46). It differs from subunit 9d only in that the total K-feldspar content exceeds

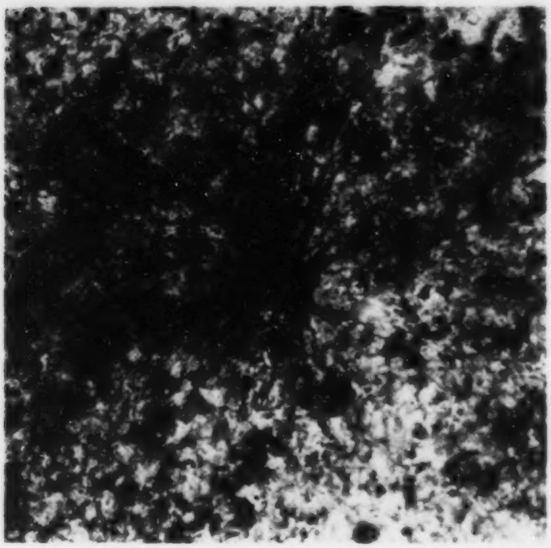


Plate 46. *Metamict allanite crystal having a typical radiating crack pattern in surrounding quartz syenite (subunit 9e). Photo and locality NN81-131, NTS 13L/4E, GR 6450.9565. Allanite crystal is about 1.5 cm in diameter.*

40 percent of the rock, of which megacrystic K-feldspar is generally more abundant. Rarely, megacrysts are not apparent but K-feldspar still dominates. Finer grained, densely K-feldspar-porphyritic to -megacrystic varieties are also rare. (This subunit yielded the date of 1576 ± 10 Ma (Brooks, 1983; Appendix 1) from the northwest part of the main outcrop area.)

Structure and Metamorphism

Structural and metamorphic features are the same as those described for the megacrystic quartz monzonite to monzogranite (subunit 9d).

Contact Relationships

Subunits 9d and 9e are gradational and intimately intermixed. The variations in K-feldspar content occur both between and within outcrops. The megacrystic quartz syenite to granite contains enclaves of quartz diorite (subunit 9b) and is intruded by granitic dykes (subunit 9h).

Subunit 9f

Quartz monzodiorite.

Distribution

The quartz monzodiorite occurs as an easterly oriented, narrow (3 km by 250 to 600 m), sinuous strip south of Vollant Lake. Other outcrops in the area, in, around and southwest of Vollant Lake are designated subunit 9b/f and are described under subunit 9b.

Description

Subunit 9f is a massive, dark-speckled white- to grey-weathering, dark-grey, medium- to coarse-grained biotite–hornblende quartz monzodiorite. The colour index varies from 10 to 30 and is defined by phenocrysts of hornblende and minor biotite and groundmass minerals of the same. Commonly saussuritized, pale-green plagioclase is the most abundant phenocryst phase. Plagioclase also occurs in groundmass aggregates that contain the ferromagnesium minerals, 8 to 12 percent K-feldspar, and 5 to 10 percent quartz. At one locality, the quartz monzodiorite grades into quartz diorite and tonalite.

Locally, small, fine-grained, dark (colour index of 25 to 40), dioritic xenoliths are abundant. Rare, medium-grained, leucocratic (colour index of 0 to 5) quartz monzonite and quartz monzodiorite xenoliths also occur. The presence of the monzonitic xenoliths distinguishes subunit 9f from subunit 9b; otherwise they are very similar. However, this relationship was noted only at the western end of the strip south of Vollant Lake, and, therefore, other localities in the Vollant Lake region are labelled subunit 9b/f. In places, the xenoliths are flattened and aligned. Epidote veins and fracture fills are common.

Structure and Metamorphism

The only structures found in the quartz monzodiorite are flattened and aligned xenoliths, some of which also contain a fracture fabric, and abundant epidote-mineralized veins and fractures. The host quartz monzodiorite appears undeformed. Saussuritization and epidotization indicate greenschist-facies alteration.

Contact Relationships

Subunit 9b/f contains large enclaves of andesite (subdivision 8a^3) and metasedimentary hornfels (subdivision 8b^3); subunit 9f contains small xenoliths of quartz monzonite (subunits 9d or 9c). It is intruded by granitic dykes of subunit 9h.

Subunit 9g

Alaskitic granite.

Distribution

Subunit 9g occurs as an easterly orientated, rectangular, 1.5 by 1 km body in the south-centre of the map area on a large island between Mackenzie and Windbound lakes, and as isolated outcrops 13 km to the west and 4 km to the east.

Description

The main subunit outcrops form a well-exposed hill of massive to strongly jointed, pink-weathering, fine- to medium-grained alaskitic granite. The colour index is very low (approximately 2) and is defined by biotite, chloritized biotite flakes up to 1.5 mm across and small magnetite grains. Plagioclase forms about 15 percent of the rock and consists of 1 to 2 mm euhedra and scattered 2 to 4 mm phenocrysts. It also occurs as rare anhedral groundmass, and as less than 1 mm euhedral inclusions within either K-feldspar megacrysts, K-feldspar groundmass or groundmass aggregates of quartz ± K-feldspar. The K-feldspar occurs as finely (3 to 5 mm) to coarsely (up to 2 cm across), tabular porphyritic laths that are zoned, euhedral and equant to elongated (up to 3:1 in ratio). The laths are continuous into groundmass aggregates of 1- to 2-mm-sized K-feldspar and larger anhedral plates. K-feldspar forms about 50 percent of the rock. Quartz similarly occurs in the groundmass as 1- to 2-mm anhedral grains, aggregates of these grains, or as single plates up to 1 cm across. The quartz distribution is patchy and it makes up about 30 percent of the rocks.

Generally, the granite exhibits a weakly to moderately developed, planar foliation consisting of aligned K-feldspar phenocrysts, a quartz-aggregate and mineral-elongation fabric and a biotite mineral fabric. In places, the rock contains profuse fractures, shears and joints, many of which are either hematite stained or smeared with a metallic veneer.

The isolated outcrop to the west is similar. However, it seems to contain only one feldspar and smaller K-feldspar laths (to 1 cm), and biotite is extensively chloritized. The isolated eastern outcrop was not visited and its position is uncertain (it could not be found at the latitude and longitude given and was added after the fact based on air-photo examination); it is included in the subunit on the basis of the description of a sample collected for dating (1403 ± 77 Ma, K–Ar biotite, granite, W. Fahrig in Lowden *et al.*, 1963, page 116).

Structure and Metamorphism

The main structure is the foliation, which consists of aligned K-feldspar laths, a quartz-aggregate and mineral-elongation fabric, and a biotite mineral fabric. Fracture sets form later structures. Chloritization of the biotite indicates that the foliation development was followed by static greenschist-facies alteration.

Contact Relationships

The alaskitic granite contains no xenoliths or dykes. It is surrounded by unexposed areas considered to be underlain by quartz monzonite (subunit 9d). These features, together with a well-demarcated boundary between the well-exposed subunit and the poorly exposed surrounds, indicate that the main body of the granite is a discrete stock.

Subunit 9h

Microgranite, and granite, aplite, microgranite, graphic granite and pegmatite dykes and veins.

Distribution

Subunit 9h occurs as a few scattered outcrops in the northern and central parts of the Unit 9 outcrop area north of Marie Lake and hence is interpreted to underlie a 4 by 6 km area near the map-area margin. The subunit is also shown on the map where it completely underlies individual outcrops, and where critical relationships to other units are demonstrated (e.g., as dykes); these occur scattered throughout the northern and western parts of the Unit 9 outcrop area. The dykes and veins are ubiquitous throughout the North Pole Brook Intrusive Suite, but are not recorded on the map in most of these cases.

Description

The main area of subunit 9h consists of a pink, massive, fine-grained, feldspar-porphyritic, glassy to aplitic microgranite. Most other localities marked on the map are similar. Locally, phenocrysts consist of K-feldspar, plagioclase and quartz. The K-feldspar is up to 1 cm across; plagioclase is up to 4 mm across and crystals are euhedral, subhedral or irregular (irregular phenocrysts may be corroded). In places, the microgranite contains minor biotite. It is pink- or white-weathering and is pink, flesh or purple on fresh surfaces. One locality contains inclusions of aplite and coarse-grained granite; another consists of a quartz-net-veined breccia, where veins up to 20 cm thick of milky and rose quartz form up to 90 percent of the rock.

Elsewhere, throughout the North Pole Brook Intrusive Suite, subunit 9h forms a ubiquitous suite of aplite, microgranite, granite, graphic granite (Plate 47), pegmatite and quartz-rich granitoid dykes and veins. Eutectic textures are common. The dykes are generally heterogeneous and/or seriate textured; several of these rock types commonly occur in the same dyke, locally in a layered fashion. The layered dykes have quartz cores in many places and aplite rims or cores elsewhere. Aplite margins commonly pass inward into graphic-textured granite. Many dykes are peg structured and the grain size coarsens inward.

The dykes exhibit *en échelon*, bayonet, hooked, bifurcating and bridge structures. Sinuous dykes are common, and dykes may contain dyke-parallel fabrics along both margins, on only one margin, or in the centres. Commonly, the dykes are associated with, or contain, epidote (Plate 48) and chlorite mineralization that may be primary or secondary.

Petrography

Microcline and plagioclase are the most common phenocrysts in the microgranites, although in places the phenocrysts consist of quartz and an opaque mineral, or hornblende, biotite and an opaque mineral. Most phenocrysts are corroded and embayed by the groundmass, and some plagioclase exhibits well-developed resorption rims and spotting. In at least one dyke, epidote is primary and the larger grains are corroded by the groundmass along with the

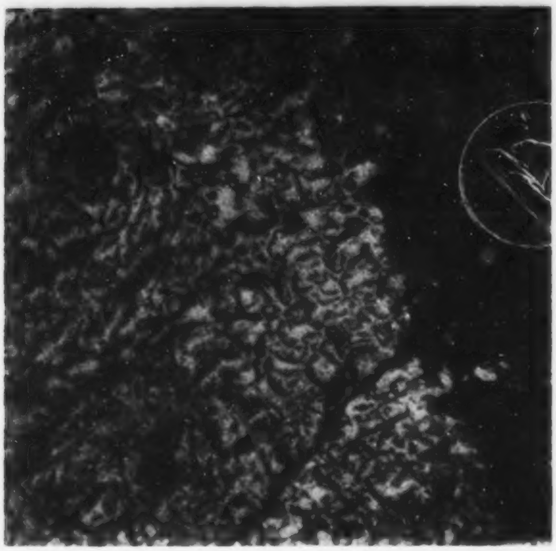


Plate 47. *Detail of texture in graphic-granite pegmatite (subunit 9h) intruding hornblende gabbro (subunit 9a). Photo GN81-CS24-30, locality 507b, NTS 13L/3E, GR 8525.8805. Diameter of coin is 2.1 cm.*

Plate 48. *Epidote–quartz core in granite pegmatite (subunit 9h). Photo GN81-CS24-21, locality G507b, NTS 13L/3E, GR 8525.8805. Diameter of coin is 2.1 cm.*

phenocrysts. Microcline is generally perthitic and some has albite rims. Hornblende occurs as colourless cores, commonly with an exsolved phase, surrounded by a green rim. Hornblende and biotite commonly form clots together and more rarely rim opaque minerals. Biotite and muscovite are groundmass phases and some form clots with quartz and/or an opaque mineral. Muscovite rarely contains lamellae of green biotite, or muscovite and biotite contain rare, red, exsolution lamellae. Some muscovite and chlorite are secondary. Most groundmass grain sizes range from 0.01 to 0.2 mm and average about 0.04 to 0.08 mm in diameter.

Structure and Metamorphism

The dykes and veins have morphologies indicative of emplacement into both tensile and shear fractures. Most of the subunit is undeformed. However, dyke-parallel fabrics are present and usually associated with epidotization.

Contact Relationships

The granitic minor intrusions are intrusive into the suite of rafts and enclaves (Unit 7) and the Mackenzie Lake group (Unit 8), and all the subunits of the North Pole Brook Intrusive Suite except the alaskitic granite (subunit 9g).

PROTEROZOIC II

Michikamau Intrusion (Unit 10)

Layered 'anorthositic' intrusion comprising leucotroctolite, and minor anorthosite, leucogabbro, gabbro, olivine gabbro, troctolite and microgranite.

Definition and Division

The Michikamau Intrusion is an approximately 2000 km^2 body of which some 450 km^2 underlies the western and northwestern portions of the map area in an approximately half-bell shape. The intrusion was mapped by Emslie (1963, 1964b) and Emslie and Wares (Emslie, 1970); in the latter paper, the name was shortened from the Michikamau anorthositic Intrusion to the Michikamau Intrusion. It forms one of a number of anorogenic granitoid and anorthositic complexes of Elsonian (Middle Proterozoic) age that intrude the Nain Province, the Rae Province and the Torngat Orogen in Quebec and Labrador (Emslie, 1978a).

The intrusion is emplaced into previously regionally metamorphosed orthogneiss (Sail Lake intrusive suite, Unit 2) and supracrustal rocks (Petscapiskau Group, Unit 5), and other less deformed supracrustal rocks (Mackenzie Lake group, Unit 8). It is unconformably overlain by an undeformed flat-lying red-bed sequence (equivalents of Unit 11) 23 km west-northwest of the northwestern corner of the map area (Figure 8). The Michikamau Intrusion is therefore defined as those plutonic rocks of anorthositic and troctolitic affinity (and related rocks) that postdate orogeneses in the older rock types (Units 2 to 8) and predate deposition of a regionally extensive red-bed succession (the Seal Lake Group and equivalents, Unit 11).

Emslie has described various parts of the Michikamau Intrusion in a number of papers (1964a, 1965, 1969, 1970, 1978b). Nunn and Noel (1982) studied only a limited number of outcrops near the margin of the intrusion and hence much of the following description is paraphrased from Emslie (1970).

The Michikamau Intrusion consists of olivine gabbro, troctolite, leucotroctolite, anorthosite, leucogabbro, gabbro and iron-rich granitoid rocks. Much of the intrusion is compositionally layered, ranging in scale from kilometres down to centimetres, and many of the layered rocks exhibit an igneous lamination. In three dimensions, the intrusion forms a rough, fault-disrupted funnel shape and was divided by Emslie (1970) into a number of lobes and sections. Almost the entire 'southern lobe' occurs in the west of the map area, and about the eastern 60 percent of the 'central section' occurs in the northwest of the map area. The intrusion is separated into five subunits on a broadly chronostratigraphic and partly structural basis, and is further subdivided on the basis of composition. Emslie's terminology is used in this report as follows: subunit 10a—marginal zone; subunit 10b—layered series; subunit 10c—anorthosite zone; subunit 10d—upper border zone; subunit 10e—transgressive group.

Age

A metabasic sample from Contact Lake gave a recalculated K–Ar (hornblende) date of 1486 ± 101 Ma (Figure 7; Wanless *et al.*, 1974, pages 52-53). The sample is either from the marginal zone or the immediately adjacent pyroxene-granulite country rock; it dates either the early crystallization of the intrusion or the thermal metamorphism of its envelope, and therefore approximates the age of intrusion. In addition, a K–Ar (biotite) date of 1408 ± 50 Ma has been obtained from the intrusion to the west of the map area (Figure 8; Emslie, 1964a).

The age of the Michikamau Intrusion is further constrained by dates of 1651 ± 3 Ma on a hypabyssal subdivision ($8a^1$) of Unit 8 (the northernmost outcrops of subunit 8a lie within the thermal aureole of the Michikamau Intrusion) and by dates of 1460 Ma and 1360 Ma on crosscutting granitoid rocks near the northern part of the intrusion, some 30 km north and northwest, respectively, of the northwest corner of the map area. The 1460 Ma age is a Pb–Pb zircon determination (Krogh and Davis, 1973), which is thought to be a reliable estimate of the minimum age of the ferroadamellite member of Emslie's transgressive group (subunit 10e).

All the dates are consistent with emplacement of the Michikamau Intrusion before 1460 Ma, intrusion of late, spatially related, Fe-rich granitoid rocks around 1460 Ma, and cooling of the intrusive complex over the next 50 Ma.

Subunit 10a–Marginal Zone

Augite troctolite, olivine gabbro, and olivine gabbronorite.

Distribution

The marginal zone in the map area is a discontinuous strip of rocks up to 1 km wide that occurs at the eastern edge of the Michikamau Intrusion adjacent to the country rocks. Although more or less continuous, locally the zone is not developed in exposed areas and may be faulted out. Exposure within the zone is generally poor.

The marginal zone contains two subdivisions. Subdivision $10a^1$ occurs west of Contact Lake, south-southeast of Hook Lake, as subsidiary northwest-oriented layers that are parallel to layering in the host-rock paragneiss (subunit 5f) in the Hook Lake area, as two outcrops in the north of Fraser Lake and as a dyke in quartzofeldspathic gneiss near the intrusion contact 1 km south of the northern boundary of the map area. Some of the outcrops included in this subdivision may be Petscapiskau Group metabasic rocks (subunits 5a or 5b). This possibility is advanced due to one or several of the following: their general conformity with the Petscapiskau Group sequence and along-strike occurrence from layers of amphibolite (subunit 5a) within that sequence; their two-pyroxene granulite mineralogy and granular metamorphic texture; the rare occurrence of quartz and quartzofeldspathic veins in the basic granulite; and the similarity of structure (e.g., Plate IIB of Emslie, 1970, south of Hook Lake) between these rocks and flattened pillows of subunit 5a in the Petscapiskau Group.

The remainder of the marginal zone consists of subdivision $10a^2$ or is undivided. Subdivision $10a^2$ occurs in the south between Michikamau and Magnetite lakes, in and west of Contact Lake, between The Buttress and Fraser Lake, in the west of Fraser Lake, and between Fraser Lake and the northern edge of the map area. Undivided marginal zone occurs mainly between Hook Lake and The Buttress.

Aeromagnetic compilations (Geological Survey of Canada, 1988) show the 'marginal zone' quite clearly and indicate that it is extensive, particularly beneath the southern lobe.

Description

Subunit 10a weathers to a brownish grey or a medium to dark rusty brown, caused by surface oxidation of ferromagnesian minerals. This weathering occurs to a depth of 1 to 2 cm, commonly resulting in a rubbly outcrop surface (e.g., Plate IIIA in Emslie, 1970, north of Fraser Lake). Fresh rocks are a medium to dark grey.

Subdivision $10a^1$ is fine- to medium-grained gabbronorite and olivine gabbronorite that also contains variable quantities of brown hornblende, magnetite and ilmenite. Typically, the gabbronorite is layered on a scale of 1 to 10 cm. The layering is well developed but diffuse and discontinuous in detail. It commonly forms metre-long lenses about a centimetre thick, and consists of variations (commonly subtle) in colour index and seams of coarser grain size and/or hornblende. Generally, the layering is not well defined on fresh surfaces but is enhanced on weathered surfaces as a more or less resistant banding. The rock possesses a distinct granular texture (Plate III, Figure 7 of Emslie, 1965) and in many places seems recrystallized.

Adjacent to contacts, the subdivision contains a 25- to 30-cm-wide, uniform, very fine grained to aphanitic chilled margin. Up to a metre from the contact, the rock regularly and abruptly increases its grain size to about 1 mm across; farther from the contact, grain size increases less abruptly, at which stage the seams of coarser grained rock are locally developed. The chilled zone is anhydrous; hornblende occurs most commonly as disseminated grains or in seams up to 2 cm wide close to, but not within, the chilled zone, and thence decreases in proportion inward. The gabbronorite attains a maximum width of 300 m in the west of Contact Lake. Between Hook Lake and Contact Lake, the two subsidiary layers vary (north to south) from 6 to 15 m thick in the western layer, and from 3 to 5 m thick in the eastern layer. The two layers contain feldspathic or quartz–plagioclase lenses or veins parallel to their compositional layering. In this area, there are rare apophyses of the olivine gabbronorite in the country rock and rare country-rock xenoliths in the gabbroic rock; the hornblende content is very variable.

At the east end of the large island in the south of Contact Lake, layering is related to variations in grain size (from very fine to medium grained) and to rare quartz veins and pods parallel to an indistinct, streaky compositional fabric. These rocks consist of two-pyroxene granulite (gabbronorite), lack hornblende and have a recrystallized appearance. Farther north, near Contact Lake, a weakly to moderately developed layering typically consists of colour-index variations, but rare, thin oxide concentrations are also present. Occurrences of gabbronorite in and north of Fraser Lake are isolated outcrops or are interlayered or gradational with coarser grained rocks of subdivision 10a². Streaks of black hornblende occur locally on the islands in Fraser Lake. The dyke at the northern boundary of the map area, as recorded by Emslie (1970), is a 15 m wide, rusty-weathering, fine- to medium-grained gabbro that has a 0.5- to 1-mm grain size at its margin, increasing to approximately 3 mm near its centre. The dyke strikes at about 125°.

Subdivision 10a² is composed of medium-grained olivine gabbro and pyroxene troctolite. Oxides (magnetite and ilmenite), rare sulphides (pyrrhotite and chalcopyrite), biotite and brown hornblende are the other constituents. The rocks are massive and layering is generally absent or minor. The layering consists of a streaky, compositional variation (similar to that in subdivision 10a¹) that decreases westward within the zone, oxide-rich layers and seams, and a weak cyclic, compositional variation that occurs toward the west of the marginal zone. The pyroxene troctolite is equigranular and igneous textured (Plate III, Figure 8 of Emslie, 1965) and has a normal grain size diameter of 3 to 4 mm. It is less granular than the gabbronorite (subdivision 10a¹). Scattered grains, clusters of grains and layers are coarse grained. In the west of Magnetite Lake, there are layers and lenses of oxide concentrations up to 10 cm thick, and metre-thick zones of 30 to 50 percent oxide minerals. These oxide-rich zones persist across a thickness of about 300 m.

An unusual relationship occurs in the marginal zone on the shore of Windy Bay. Nodular-weathering, spotty, medium-grained leucotroctolite typical of both the marginal zone in the local area and also of much of the layered series (subunit 10b) appears to be intruded by another phase. The younger(?) phase consists of intergranular-textured, medium to very coarse grained (pegmatitic) gabbro and leucogabbro or troctolite and leucotroctolite (ferromagnesian species unknown). It occurs as coalescing dykes, sheets and net-veins, mostly enclosing metasedimentary hornfels enclaves (Mackenzie Lake group, subdivision 8b¹).

Petrography

Texturally, rocks of subdivision 10a¹ are thoroughly granoblastic, polygonal granulites (Plate III, Figure 7 of Emslie, 1965). Plagioclase, augite and opaque minerals are essential components; orthopyroxene and olivine and/or brown hornblende are also common. The colour index normally varies from 45 to 60. Hornblende commonly forms a rim around opaque minerals against olivine and augite, and less commonly against plagioclase.

Chlorite and carbonate are ubiquitous alteration products, especially in veins and fracture fills, and may completely pseudomorph olivine or clinopyroxene. Epidote and serpentine occur in similar, but more localized, fashion. Chlorite replacement is commonly accompanied by exsolution of an opaque mineral, and quartz also occurs in the fractures.

Subdivision 10a¹ contains a weak foliation defined by plagioclase, augite, olivine, hornblende and some opaque minerals, that is paralleled by hornblende-rich streaks. This structure may be either a weak (or relict) dynamic foliation or a relict lamination or flow fabric.

The medium grained olivine gabbro and augite troctolite (subdivision 10a²) is igneous textured in contrast to the finer grained gabbronoritic rocks (subdivision 10a¹). The gabbroic and troctolitic rocks consist of an anhedral aggregate of plagioclase, augite, olivine and opaque minerals, in which some plagioclase and olivine attain broadly subhedral form (Plate III, Figure 8 of Emslie, 1965).

Structure and Metamorphism

The subunit contains primary structures that include compositional layering and, locally, a chilled margin, apophyses and xenoliths. The layering in the inner parts of subdivision 10a² (augite troctolite) and the oxide concentrations indicate compositional variations of igneous derivation. However, the streaky compositional layering, parallel quartz and quartzofeldspathic veining, and pyroxene-granulite mineralogy and texture in subdivision 10a¹ (gabbronoritic rocks) are consistent with pyroxene-hornfels-facies recrystallization overprinting earlier regional fabrics typical of those found in the Petscapiskau Group (Unit 5). (Hence the alternate subunit/subdivision designations, on Map 93-19, of some layers as 10a¹/5a/b.) Granular textures may, in part, be primary or, where the rock is clearly recrystallized, have resulted from thermal metamorphism of its own carapace by the bulk of the intrusion.

Younger structures are confined to faulting and greenschist-facies mineralization of joints and fractures. Locally, in probably related developments, some ferromagnesian minerals are pseudomorphed by combinations of chlorite, epidote, carbonate and serpentine. Shearing is developed along one of the faults south of Contact Lake and along Narrow Lake.

Contact Relationships

The gabbronoritic (subdivision 10a^1) and troctolitic (subdivision 10a^2) rocks appear to be gradational (Emslie, 1970) based on decreases in granular texture and layering and an increase in grain size (together with the development of igneous textures) inward from subdivisions 10a^1 into 10a^2.

Gabbronorite contains inclusions of pelitic paragneiss (subunit 5f) south of Hook Lake. Gabbro or troctolite (subdivision 10a^2) contains enclaves of metasedimentary hornfels (subdivision 8b^1) on the shore of Windy Bay. The gabbro dyke at the northern boundary of the map area intrudes quartzofeldspathic gneiss (subunit 2b). Chilling, apophyses, xenoliths, thermal metamorphism and the zoned country-rock aureole are further evidence that the marginal zone intrudes the Sail Lake intrusive suite (Unit 2), the Petscapiskau Group (Unit 5), the gneissic tonalite dykes (Unit 6) and the Mackenzie Lake group (Unit 8). The marginal zone is in fault contact with the Petscapiskau Group (Unit 5) for much of the southern portion of the boundary.

Subunit 10b: Layered Series

Leucotroctolite and minor troctolite, anorthosite and leucogabbro.

Distribution

The layered series underlies almost all of the outcrop area of the Michikamau Intrusion within the map area. Troctolite (subdivision 10b^1) occurs as a discontinuous, north-northwesterly oriented layer, 2 km long by 0.5 km wide, between The Buttress and Hook Lake, and as a fault-bounded, northerly elongated triangular wedge, 2 km long and 1 km across, approximately 7 km northwest of The Buttress. Leucotroctolite (subdivision 10b^2) occupies the bulk of the rest of the subunit outcrop area; anorthosite (subdivision 10b^3) occurs as layers in leucotroctolite, particularly in the southern lobe. Layered gabbro (subdivision 10b^4) occurs only on the islands in the Bay of Islands in the northwest corner of NTS map area 13L/4 where it has a minimum (map) width of 2 km.

Description

The layered series is composed of three main lithological subdivisions: troctolite (subdivision 10b^1, colour index greater than 25), leucotroctolite (subdivision 10b^2, colour index of 5 to 25) and anorthosite (subdivision 10b^3, colour index less than 5). It also contains rare gabbroic rocks (subdivision 10b^4). Olivine-bearing members of the layered series crumble on weathering and the ground is commonly strewn with a veneer of friable crystal gravel. Anorthosite and gabbroic rocks are more resistant.

The troctolite is a rusty-brown-weathering, medium-grained (2 to 4 mm) rock containing 20 to 30 percent of olivine and minor clinopyroxene, orthopyroxene and oxide minerals. The olivine is mostly fresh and contains only minor serpentine. Commonly, the subdivision is composed of layers, 2 to 10 cm thick, some of which are modally rhythmic.

Subdivision 10b^2 consists of leucotroctolite containing layers of anorthosite, troctolite to melatroctolite (colour index > 50) and dunite. (Where the anorthosite layers are wide enough, they have been separated to form subdivision 10b^3 on the map (Map 93-19).)

The leucotroctolite is a light- to medium-grey- or brownish-weathering rock. Anorthosite layers are light-grey weathering; more olivine-rich rocks than the leucotroctolite are brownish to rusty weathering. All rocks are medium to dark grey on fresh surfaces; rarely they exhibit a greenish cast. The leucotroctolite contains 5 to 20 percent of olivine and minor orthopyroxene, clinopyroxene, Fe and Fe–Ti oxides, biotite and hornblende. The other rock types contain more, or less, olivine, and most olivine is fresh.

Layering is commonly subtle and best seen on weathered surfaces. It is mostly a mineralogical layering of a cyclic (alternating) or rhythmic (gradational) nature that occurs on scales of 0.3 to 1 m up to decametres across (e.g., Plate XVIB of Emslie, 1970, northwest of Fraser Lake); some layers of anorthosite (subdivision 10b^3) exceed 100 m in thickness. Olivine-rich and dunite layers mostly are 1 to 4 cm thick but reach 1 m across. Less obviously, some layering is a result of changes in the habit of plagioclase, and much less commonly a non-compositional grain-size layering is present. Rarely, layers consist of zones of pods and irregular patches of mostly more anorthositic material of a coarse to very coarse grain size (e.g., Plate XB of Emslie, 1970, southwest of Hook Lake).

Igneous lamination is abundant in the leucotroctolite but less so in the anorthosite layers, and, commonly, laminated leucotroctolite alternates with equant anorthosite (however, the reverse also occurs). The presence of igneous lamination is very variable, even for adjacent layers of similar plagioclase grain size and shape.

Most plagioclase crystals in the leucotroctolite are 0.2 to 3 cm in diameter (predominantly 0.5 to 2 cm). Scattered megacrysts having a mean grain size of 5 by 10 cm occur, but rarely form more than a few percent of the rock. The plagioclase ranges from equant to oblate or tabular, and is both euhedral and anhedral. Rarely, it displays a pale-blue chatoyance. Olivine is generally smaller than plagioclase and has a common grain-size range of 2 to 5 mm, although some crystals reach 10 cm in diameter. Commonly, the olivine is very irregular and moulded around plagioclase laths; rarely, it forms larger poikilitic crystals and patches (Plate 49).

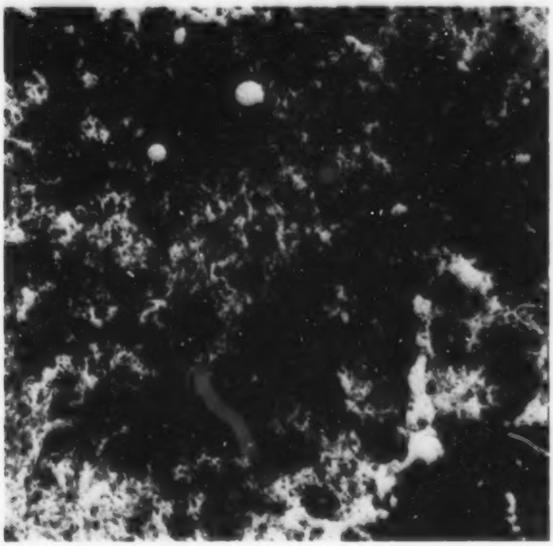


Plate 49. *Ferromagnesian heteradcumulate(?) patches in leucotroctolite (subdivision $10b^2$) consisting of olivine (dark grey and black) and minor augite. (The two largest dark patches at top left and bottom right are moss and gravel.) Photo GN81-CP36-2, locality G687a, NTS 13L/5W, GR 4575.1668. Length of clinometer is 10 cm.*

Subdivision $10b^3$ comprises anorthosite layers ranging in thickness from several centimetres to over 100 m. Only the wider layers are indicated on the map, of which the largest is greater than 200 m wide (1 km north of Big Island Lake). These layers are more resistant than the olivine-bearing subdivisions and less crumbly. Most are continuous across the outcrop width; however, some are wedge like and occur as convex-down lenses, or have thicker centres and thin abruptly along strike where they peter out. The anorthosite varies from zones of mottling or irregular pods to rectiplanar layers, and from sharply defined to gradational boundaries on either the top, bottom or both margins.

Plagioclase in anorthosite layers is uniform in grain size (mostly 0.5 to 1 cm long). Commonly, it has a xenomorphic-granular texture; more rarely it is tabular in habit and locally defines a lamination. Pyroxene is more abundant than olivine in the intercumulus ferromagnesian minerals, which occur as small grains or clusters of crystals and, in some layers, as poikilitic patches.

Subdivision $10b^4$ is layered, medium-grained, plagioclase-megacrystic leucogabbro. The rock has a distinct light-greenish-brown cast on weathered surfaces and is medium to dark olive green or greenish grey where fresh. The general grain size diameter is 2 to 5 mm and the larger plagioclase crystals range up to 0.5 by 2 cm. Most plagioclase forms an isotropic fabric of euhedral laths; laminated layers are rare. The colour index (≤ 20) is defined by pyroxene and minor magnetite, ilmenite and olivine. Pyroxene is granular, non-poikilitic, and probably a cumulus mineral. The layering consists of 1- to 8-cm-thick layers that are pyroxene or oxide rich and occur in groups 1 to 3 m thick, interspersed with anorthosite layers up to a metre or more thick; most layers are tabular and some pinch out. Variations in colour index from one layer to the next range from subtle to marked changes, and within layers the colour index may be homogeneous or vary rhythmically.

An olivine-gabbro dyke, recorded by Emslie (1970) as intruding leucotroctolite 2 km south of Big Island Lake but not shown on his map because it is less than a metre wide, may be a dyke of subdivision $10b^4$. The dyke has a grain size of 0.5 to 2 mm.

Petrography

Examples of contrasting adcumulate textures in the layered series are given by Emslie (1965). In subdivision $10b^2$, leucotroctolite is composed either of strongly laminated tabular plagioclase with limited adcumulus growth and interstitial olivine (*op. cit.* Plate IV, Figure 9), or of plagioclase with a more equant habit and strong adcumulus growth moulded on scattered cumulus olivine (*op. cit.*, Plate IV, Figure 10).

Structure and Metamorphism

Faulting is the main structure affecting the layered series, and the rocks are broken up into blocks of variable size and orientation (see Map 93-19). Although changes in strike are not major within the map area, ranging mostly from west-northwest to north-northeast, dips vary from subvertical to very gentle. These variations have been used by Emslie (1970) to determine the locus of some faults, many of which also exhibit shearing. Locally, the layered series contains a weak foliation or a fracture fabric, e.g., in Narrow Lake and between Narrow Lake and the Bay of Islands.

Surface oxidation of olivine is the main alteration feature. Minor serpentinization and greenschist-facies mineralization, associated fractures and shearing also occur.

Contact Relationships

Troctolite (subdivision $10b^1$) outcrops next to the marginal zone or as fault-bounded wedges within leucotroctolite (subdivision $10b^2$). Emslie (1970) interpreted the troctolite as representing lower parts of the layered series and postulated that they pass gradationally up into subdivision $10b^2$ leucotroctolite.

The leucotroctolite contains xenoliths of quartzite (subunit 5e) just west of the gossan between Hook Lake and The Buttress. On the south shore of Contact Lake, in leucotroctolite just west of the marginal zone (subunit 10a), there are several seriate-textured pyroxenite xenoliths (Emslie, 1970) with grain sizes of 0.2 to 1 cm across. The xenoliths are recrystallized and may have been country rocks (e.g., Petscapiskau Group, subunits 5a or 5b), marginal zone rocks or some other cognate inclusions. Elsewhere, the marginal zone is missing and the layered series is in fault contact with country rocks, e.g., Petscapiskau Group amphibolite (subunit 5a) and quartzite (subunit 5e) near Magnetite Lake.

Subunit 10c: Anorthosite Zone

Anorthosite and minor leucogabbro.

Distribution

The anorthosite zone occurs north of the Bay of Islands in the southwest corner of NTS map area 13L/5 (Map 93-19). It occupies an approximately triangular, fault-bounded area of about 8 km^2.

Description

The anorthosite zone comprises anorthosite (colour index < 5) containing minor discontinuous layers, zones and patches of leucogabbro (e.g., Plate XVIIIA of Emslie, 1970, northwest of the Bay of Islands). The rocks are grey- to white-weathering and generally unaltered.

Plagioclase grains are very heterogeneous in size, are mostly 1 to 3 cm in diameter, but range from 0.5 to greater than 6 cm. Most outcrops contain individual crystals or clusters of plagioclase having grain sizes of up to 50 cm in diameter. The plagioclase is equant to tabular, exhibits isotropic or planar (laminated) fabric and is blue grey to dark grey on fresh surfaces. Bright iridescence is common, displaying a zoning from bronze cores through green to blue rims.

Interstitial minerals consist of orthopyroxene, clinopyroxene, magnetite, ilmenite, apatite and rare sulphides. Pyroxene also forms poikilitic plates from 2 to 25 cm in width.

Variations in the mineralogy and textures define layering. Compositional variations consist of leucogabbro patches and discontinuous layers, some of which are due to the presence of large poikilitic pyroxene. The textural layering is defined by variations in grain size, morphology, grain-size distribution and degree of lamination of the plagioclase. Most layers are irregular and ill defined.

Petrography

Similar contrasts in texture occur in the anorthosite zone as are present in the layered series (subunit 10b). They are shown by Emslie (1965) as anorthosite containing subequant, anhedral adcumulate-cemented plagioclase (*op. cit.*, Plate V, Figure 11) or leucogabbro containing laminated plagioclase cemented by intersertal to heteradcumulate plates of augite (*op. cit.*, Plate V, Figure 12).

Structure and Metamorphism

The subunit is faulted. Alteration zones, some associated with the faulting, contain green amphibole, chlorite, sericite and zeolites. Rare, rusty oxidation patches also occur.

Contact Relationships

The anorthosite zone is entirely fault bounded within the map area and occurs adjacent to leucotroctolite and layered gabbro (subdivisions $10b^2$ and $10b^4$, respectively). Outside (north) of the map area, the anorthosite zone is gradational up into subunit 10d upper border zone leucogabbronorite (Emslie, 1970).

Subunit 10d: Upper Border Zone

Leucogabbronorite.

Distribution

The upper border zone occurs as four small localities submerged in, or near the eastern shore of, the ria north of the Bay of Islands.

Description

The upper border zone consists of medium- to coarse-grained, plagioclase–megacrystic leucogabbronorite. The rocks are light-rusty-brown-weathering and dark grey where fresh. Grain size is very heterogeneous and contains 4- to 6-cm-plagioclase megacrysts scattered throughout a subequant plagioclase-rich host, which has grain sizes that range from 0.5 to 2 cm in diameter. Rarely, the plagioclase has a less heterogeneous grain-size distribution, is tabular and laminated.

The colour index is 10 to 35 and is defined by orthopyroxene, clinopyroxene, rare oxides and rare apatite. The pyroxene varies from interstitial to poikilitic. Locally, variations in the colour index impart a weak layering to the subunit.

Structure and Metamorphism

The upper border zone is faulted; no other structures or alteration were noted by Emslie (1970).

Contact Relationships

At one locality within the map area, the upper border zone conformably overlies a layer of anorthosite (subdivision $10b^3$ of the layered series). The other localities are isolated but outcrops of other rock types from nearby consist of leucotroctolite (subdivision $10b^2$) and anorthosite (subdivision $10b^3$). North of the map area, about 37 km north of The Buttress, the upper border zone gradationally overlies subunit 10c (the anorthosite zone; Emslie, 1970) close to the top of the intrusion (*ibid.*).

Subunit 10e: Transgressive Group

Granite dykes.

Distribution

Within the map area, the transgressive group occurs as a single locality, 100 m from the southern contact of the intrusion and 200 m east of the shore of Michikamau Lake, and as dykes at several places on the north shore of, and at the head of, Windy Bay. The first outcrop is elongated in a northeasterly direction and the dykes have a similar strike.

Description

The first locality consists of a pink, homogeneous, anhedral-textured biotite microgranite. It contains abundant epidote veins and fracture fills, and the biotite is extensively chloritized. The dykes in Windy Bay are recorded by Emslie (1970) as small dykes of white granite that intrude leucotroctolite. One dyke is shown on the map; it has a strike and dip of 050°/50° SE.

Regionally, Emslie (1970) described the transgressive group as crosscutting iron-rich granitoid rocks that are spatially related to the Michikamau Intrusion and that include ferrogranodiorite, ferroadamellite, ferrodiorite, ferromonzonite and ferrosyenite. They are best exposed 43 km due north of The Buttress, where a Pb–Pb age of 1460 Ma was obtained (Figure 8; Krogh and Davis, 1973). It is not known whether or not any of the localities in the map area are iron rich.

Structure and Metamorphism

The microgranite is not foliated but contains abundant fractures and greenschist-facies alteration.

Contact Relationships

Contacts at the first outcrop are not exposed. The elongated outcrop is assumed to represent an intrusive sheet; alternatively the abundance of greenschist-facies-related fracturing suggests that the microgranite is a fault-bounded slice of either subunits 10e or 9h. The white granite dykes intrude leucotroctolite (subdivision $10b^2$).

Seal Lake Group and Equivalent Rocks (Unit 11)

Arenaceous and rudaceous sedimentary rocks and minor basalt, gabbro, diabase, mafic tuff and stromatolite-bearing float.

Definition and Division

The Seal Lake Group (subunit 11a) occurs along the eastern margin of the map area where it is contiguous with the main outcrop area of the group. The main area is an approximately 6000 km^2, broad synclinorium containing arenaceous, rudaceous and lesser argillaceous sedimentary rocks, basaltic flows, and gabbro and diabase sills. It is a predominantly reddish, fluviatile sequence containing minor shallow-marine rocks. The Group was named by Evans (1952) and divided stratigraphically by Mann (1959). Brummer and Mann (1961, in the major paper on the group), Gandhi and Brown (1975), and Baragar (1981) made minor revisions, all to the east of the present map area and part of the area to the east was mapped at 1:250 000 scale by Roscoe and Emslie (1973). Emslie (1964b) mapped the Group in the present map area, and subsequently inferred a Neohelikian (Late Middle Proterozoic) age (Emslie, 1970) for red beds that he regarded as equivalent at the north end of Michikamau Lake, 20 km west of the northwest corner of the map area (Figures 5 and 8).

Regionally, the Seal Lake Group lies unconformably on Archean gneisses of the Nain Province to the east, on the North Pole Brook Intrusive Suite (Unit 9) and a felsic volcanic porphyry (the Letitia Lake Group) to the south, and on the Harp Lake Intrusive Suite (an Elsonian anorthositic complex) to the north (Thomas, 1985, page 336); it is not overlain or intruded by younger rock types (*ibid.*). The group is, however, affected by the Grenvillian Orogeny. Therefore, it is defined as a predominantly red bed and mafic igneous succession that postdates the plutonic suites and the felsic porphyry but predates the Grenvillian Orogeny.

Low (1896) makes the first reference to 'Cambrian red beds and limestone' from the Michikamau area, and probably noted the calcareous rocks of subdivision $11b^4$ (this report) before they were submerged by the flooding of the Smallwood Reservoir. Subsequently, Emslie (1970) noted that red beds were unconformable on the Michikamau Intrusion (Unit 10) 23 km west-northwest of the map area. Nunn and Noel (1982) recorded a similar relationship between red beds and the granitoid rocks of the North Pole Brook Intrusive Suite (Unit 9) on the south shore of Windbound Lake 6 km south of the map area. Although not recognized at the time, Nunn (1981) mapped the same unconformity between red beds and granitoid rocks 15 km south of the southwest corner of the map area (Richard Wardle, personal communication, August, 1984). These rocks (subunit 11b) are correlated with the Seal Lake Group. Clast petrology, for example, indicates the same regional relationships for each subdivision of subunit 11b as for subunit 11a, and the unconformity may be present at the outcrops of subdivision $11b^2$.

Mann (1959) and Brummer and Mann (1961) divided the Seal Lake Group into several stratigraphic formations. These relationships were not specifically determined in the present map area, and the Seal Lake Group and equivalent rocks are divided according to rock type and outcrop area, respectively, in this report. However, the interlayered basic rocks and grey arenite (subdivisions $11a^{1,2,3}$) are thought to belong to the basal Bessie Lake Formation of Mann (1959), and the red beds and tuffs (subdivisions $11a^{4,5}$) to correlate with the Majoqua Lake Formation. The latter is reported by Mann (1959) to have been named by Frobisher Company workers in the early 1950's and regarded by him (*ibid.*) as equivalent to the Bessie Lake Formation but occurring on the northern limb of the Seal Lake synclinorium.

Age

Volcanic flows and gabbro sills dated by Baragar (1978) west of the map area gave a recalculated Rb–Sr whole-rock date of 1323 ± 90 Ma (Figure 8). An intermediate tuff from 8 km north of the northwest corner of the map area yielded a recalculated K–Ar (whole-rock) date of 854 ± 125 Ma (Figure 8; Wanless *et al.*, 1967, pages 118, 119). Emslie (*ibid.*, page 119) interpreted this to be a young age due to argon loss from a probable Seal Lake Group rock. The plutonic suites that the Seal Lake Group and equivalents unconformably overlie give the following ages (Figure 8): 1460 Ma (Pb–Pb zircon on the Michikamau Intrusion; Krogh and Davis, 1973), 1450 Ma (Pb–Pb zircon on the Harp Lake Intrusive Suite; Krogh and Davis, 1973), 1654 Ma [U–Pb titanite (Krogh, 1983) and Rb–Sr whole-rock isochron (Fryer, 1983) on the North Pole Brook Intrusive Suite] and, more specifically, 1327 ± 4 Ma (U–Pb zircon on the Letitia Lake Group; Fryer, 1983). The Seal Lake Group is therefore Middle Proterozoic. In the map area, subunit 11b occurs either within protected augen of no Grenvillian deformation, or is north of the effects of the Grenvillian Orogeny [dated at around 1000 Ma (Stockwell, 1973) and refined for eastern (Schärer *et al.*, 1986; Schärer and Gower, 1988) and western (Nunn *et al.*, 1985; Connelly, 1991) Labrador, respectively]; it might, therefore, be a younger red-bed sequence. However, the lithological similarities are strong, contact relationships are similar, and hence the correlation is made.

Subunit 11a: Seal Lake Group

Red bed sandstone and conglomerate, metabasalt, grey quartzite and metagabbro sills.

Distribution and Subdivision

The Seal Lake Group forms two areas along the eastern boundary of the map area. The larger area is a narrow, southerly pointing, 270 km² triangular wedge that is 8 km wide at the northern edge of the map area and narrows to nothing 35 km to the south; it is underlain exclusively by red beds (subdivision 11a^4) except in the extreme northeast corner of the outcrop area, which is underlain by tuff (subdivision 11a^5). The smaller area is also southerly elongated and has a rough crescent shape, 6 km long and 1 km wide, in the area immediately south of Marie Lake. It is underlain by undifferentiated subunit 11a or by approximately north-northwest-trending, 0.3- to 0.5-km-wide strips of metagabbro, metabasalt and grey quartzite (subdivisions 11a^1, 11a^2 and 11a^3, respectively). Two localities containing red sandstone (subdivision 11a^4) occur in this southern area. The subdivisions are based upon petrological variations.

The western margins of both areas are irregular due to faulting. Both areas are contiguous to the east with the main (approximately 6000 km²) area of the Seal Lake Group.

Description

Subdivision 11a^1 is brown- or green-weathering, massive, dark-grey, black or green, metagabbro to diabase. It contains a relict ophitic texture; rarely, plagioclase laths occur in clots and as larger porphyritic grains up to 3 mm across. Both plagioclase and the ferromagnesian groundmass appear recrystallized in some samples. The rock is green where it is strongly chloritized. Small basalt dykes cut the metagabbro at the locality in Marie Lake, 150 m east of the map edge.

Subdivision 11a^2 is a brown- or green-weathering, blocky or well-jointed, dark-grey or dark-green, fine-grained metabasic rock (probably metabasalt). Locally, the jointing is curvilinear hinting at pillow structures; elsewhere, some zones are more massive, some areas are vesicular, and, throughout, parts of the rock are weakly to moderately foliated. The rock consists predominantly of 0.2 to 0.5 mm laths (rarely to 1.5 mm) and scattered tiny oxide grains in an altered ferromagnesian groundmass. At one locality, ovoid, chloritic patches up to 1 cm across lie in the foliation. Elsewhere, these patches are smaller, less regular in shape or orientation, or are absent. Chloritization, possible actinolitic amphibole and epidote alteration, and irregular, reddish patches of hematitic alteration are common, especially where the rock is more strongly foliated. Chlorite occurs on slickenside joint faces. Small laths of plagioclase are more conspicuous in areas of hematite alteration, where they have a pinkish colour.

Subdivision 11a^3 comprises light-grey and white, fine- to medium-grained, massive to well-bedded arenite. The arenite ranges from quartzite to subarkose in which the feldspar occurs as white grains in a grey quartz groundmass; a few percent of very fine grained heavy minerals are scattered throughout. Beds are 7 to 80 cm thick, are ungraded, have plane top and bottom surfaces, and commonly contain internal, parallel lamination or fine bedding.

Subdivision 11a^4 consists of a fine- to coarse-grained red-bed sequence. Most beds are pale- to salmon-pink, red- or maroon-weathering, although well-sorted arenite also weathers orange, buff, cream, yellow-brown, brown or grey. Coarse-grained conglomerate is red- to grey-weathering. Fine-grained rocks or poorly sorted coarser grained rocks having a shaly component are red-, mauve- or maroon-weathering; deep-red or maroon soil and talus are commonly associated with them. Fresh surfaces are generally similar in colour or darker than their weathered equivalents. Red parts of the sequence contain yellow to buff reduction spots and, more rarely, reduced bedding-plane surfaces; pink and the various yellowish parts of the sequence contain red oxidation spots. Rarely, the two redox states are complexly intermixed.

Most of the succession consists of fine- to coarse-grained, moderately well-sorted arenite, poorly sorted grit, and clast- or matrix-supported granule to small-pebble conglomerate. The arenite varies from indistinctly bedded to well-bedded, commonly parallel-laminated or crossbedded, rarely graded tabular sheets that are 4 cm to greater than 1 m thick. Thirty-five- to 60-cm-thick layers dominate, and most beds have either plane surfaces or wavy, rippled tops. Some finer grained beds are colour graded. The conglomerate occurs as tabular sheets up to 2 m thick that usually contain several amalgamation surfaces. It also forms groups of thinner layers (centimetre-scale) that are tabular or lenticular, in which the coarser grained fractions in either clast- or matrix-supported beds are commonly graded. The poorly sorted layers are characterized by a coarse-sand to fine-granule matrix, by scattered granules and small pebbles in a shaly-sand matrix (Plate 50), by shaly partings and thin shaly-siltstone layers, by flat lenses of coarse-grained material in fine (or vice versa), and by darker red colours. Commonly, clast-supported granule-conglomerate layers are only one or two clasts thick, and, although locally abundant in groups of beds over thicknesses of 0.1 to 1 m, are separated from the next group by several metres of better sorted arenite. Thus, they form only about 5 percent of the succession in these areas. Granules and pebbles are angular to subrounded, equant to triaxial in shape, and rarely seem imbricated. Siliceous sand grains are subrounded whereas feldspar and many lithic grains are more angular.

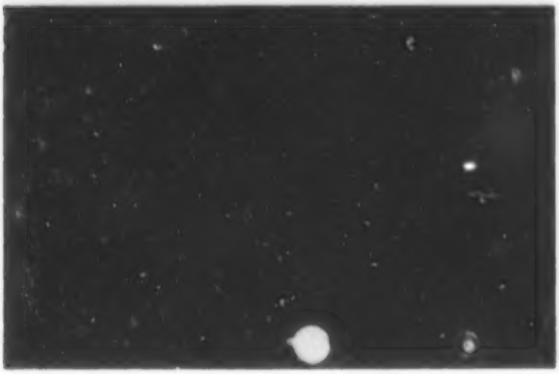


Plate 50. *Deep red, muddy sandstone (subdivision 11a^4) containing angular gravel lag deposit. Photo GN81-CP41-3, locality G786a, NTS 13L/3E. Length of clinometer is 10 cm.*

Grey, milky and blue-grey or blue quartz dominate the sand to pebble size fractions. Quartzite and pink K-feldspar also attain pebble size, as do rare, more irregularly shaped clasts of siltstone or shale (up to 2 by 5 cm). Feldspar contents result in a range from feldspathic arenite toward arkose; quartzite, heavy minerals, and red, yellow and dark lithic grains and granules are usually minor. Most of the arenite is compact and commonly exhibits a twinkling, recrystallized-looking cement.

At the contact in the gorge east of Sail Lake, the red beds (subdivision 11a^4) consist of a granule to pebble conglomerate. It is composed of rounded quartz and K-feldspar clasts about 1 cm in diameter, and milky-quartz clasts up to 3 cm across in graded and crossbedded sheets. Conglomerate at this locality is distinctly coarser than the layers farther downstream. However, elsewhere, localities near the western margin of the subunit reflect only the normal clast-size variations for the sequence. The coarsest layer occurs along the Desolation River, 2 km west of the map boundary. It is an unsorted, rounded to subrounded, cobble conglomerate that has a coarse-grained grit matrix. The coarser cobbles are up to 25 cm across and consist of microgranite and minor gneiss; the finer cobbles include milky quartz and quartzite.

Current directions based on foresets, foreset-bedding intersection lineations and asymmetric ripples vary in a range toward the south-southeast to the southwest (5 readings).

The beds have varied and inconsistent strike. In the north, they are subhorizontal or gently to moderately dipping and are warped and gently folded, except along the western margin, where they are very steeply dipping and strike parallel to the contact. From the Desolation River southward, the beds are moderately folded and locally, along the river, are slightly overturned toward the northwest. Folds are periclinal exhibiting gentle to moderate plunges of approximately eastward or westward orientation.

Quartz veins ($\leq$ 1 cm wide) are abundant locally. The veins occupy tension gashes and commonly *en échelon* brittle and shear fractures. The quartz is milky, anhedral or fibrous, and locally exhibits slickensides.

Subdivision 11a^5 consists of basaltic to intermediate tuff and is probably interlayered with thin red beds typical of subdivision 11a^4. The subdivision was not defined in the map area but is extrapolated from the map of Roscoe and Emslie (1973) to the east where they describe it as green basaltic tuff. The dated sample from 8 km north of the map area is a 'light grey-green lithic 'tuff' made up of 60 percent unsorted volcanic fragments up to 1.5 inches across .... in an aphanitic matrix' (Emslie *in* Wanless *et al.*, 1967, page 119). This tuff is associated with red arkose and conglomerate.

Petrography

The metagabbro (subdivision 11a^1) exhibits a coarse ophitic texture of clinopyroxene plates up to 7 mm across enclosing randomly oriented laths of plagioclase up to 0.3 by 1.2 mm in length. Plagioclase is strongly saussuritized or replaced by bundles of a colourless felted aggregate. The larger opaque grains subophitically enclose plagioclase laths and commonly consist of a dark-brown phase and an exsolved (octahedrally?) black phase. According to Park and Roy (1979), the dark-brown phase represents selective to complete martitization, which leaves black skeletons of the original exsolved ilmenite phase. Blocky to irregular, non-pleochroic, pale-brown to pale-orangish-brown, isotropic grains and rare narrow prisms of the same mineral are unidentified. Grains of blue chlorite that, locally, envelope plagioclase and have equant, euhedral to rounded form, are assumed to be pseudomorphed ferromagnesian phenocrysts. Where chlorite replacement is only partial, the relict material looks like clinopyroxene. Fractures and veins are filled by chlorite ± quartz, and the whole rock is considerably altered.

The metabasalt (subdivision 11a^2) has an intergranular to subophitic texture that is much finer grained than related textures in the metagabbro (subdivision 11a^1). Plagioclase laths reach a maximum length of 0.7 mm, and most are 0.2 to 0.3 mm long with aspect ratios commonly in excess of 10:1. They are enclosed in patches of two to four plates of 0.1- to 0.25-mm-long clinopyroxene. The laths are random or have formed into stellate aggregates. The clinopyroxene has a finely lamellar structure (exsolution), in which both phases have the same extinction angles of 30 to 45 degrees. Opaque minerals form long needles and ill-defined, stubby-to-more-delicate, dendritic, quench-textured forms up to 0.5 mm long. Epidote occurs as abundant, discrete, granular grains, and as aggregates replacing plagioclase along with minor chlorite. The basalt is extensively altered to greenschist-facies assemblages, either dynamically or statically, consisting of chlorite–epidote–opaque mineral. Vesicles are filled with drusy-textured chlorite or epidote, chlorite with carbonate cores, or epidote + chalcedony; veins contain epidote, chlorite and rare muscovite.

The clasts and sand grains in the grey arenite of subdivision 11a^3 consist of quartz, quartzite, chert, microcline, plagioclase, opaque minerals, ribbon and braided microperthite, very fine oval grains of unidentified brownish material, zircon, graphic grains and orange-brown fine grains. Relicts of an original rounded-to-subrounded, good-to-poor-sphericity clastic texture are accentuated by cloudy outlines between grains and syntaxial cement. Strain patterns and rare recrystallization or subgrain development are not controlled by the original grain outlines.

Most layers in the red-bed sequence of subdivision 11a^4 contain grains of quartz, quartzite, foliated quartzite, possible vein quartz, chert (perhaps including felsic volcanic rock), orthoclase, microcline, plagioclase and opaque mineral. One feldspar grain consisted of a 6-mm-across, broken, zoned orthoclase megacryst containing small inclusions of igneous biotite and quartz. Less common are grains of myrmekite, plagioclase-phyric aphanitic metavolcanic rock, possible flow-banded acid-volcanic rock, and polycrystalline granoblastic aggregates of plagioclase, hornblende and apatite. Muscovite is probably also detrital. Foliated, hematitized siltstone may be intraclastic (in which case aligned phyllosilicates probably define a relict compaction fabric). The red beds approximate subarkosic compositions.

The rocks exhibit well-developed clastic textures that range from subrounded to angular and from moderate to good sphericity in most clast types. In many rocks, there is no obvious cement, just finer grained clastic material. However, in some examples, the arenite is cemented by coarse plates of sparry carbonate and lesser amounts of a yellow-brown to red-brown matrix. Typically, the fine- to medium-grained sand (0.15 to 0.4 mm) is enclosed in plates of spar up to 1.5 mm across. Variations in cement type and proportion are layered at millimetre scale in some samples; these variations commonly mirror changes in grain size. Locally, detrital mica defines a fissility in fine-grained layers and laminae.

Structure and Metamorphism

The basaltic tuff (subdivision 11a^5) occuring in the northeasternmost part of the map area is flat lying and undeformed. The red beds (subdivision 11a^4) are folded but uncleaved. The folds are gentle, open, periclinal warps that have gentle west- or east-oriented plunges in the north. They become increasingly tight southward, locally obtaining steep to subvertical or slightly overturned limbs (Desolation Lake area). Some quartz veining is contemporaneous with the folding. The 'twinkling' nature of the carbonate cement may represent the onset of recrystallization in the subunit but could alternatively be primary.

South of Marie Lake, subunit 11a is folded. The basic members of the sequence vary from massive through weakly to moderately foliated, whereas the arenite is uncleaved and only locally strained internally. Deformation in this area appears to have involved more intense strain than that in the red beds farther north (subdivision 11a^4). It took place in the greenschist facies, e.g., chlorite–epidote–actinolite assemblages in the basic rocks, chlorite–epidote–carbonate–quartz in vesicle fills, and epidote–quartz–chlorite ± muscovite assemblages in veins and fracture fills. The varied attitudes of the foliation in this area might be the result of refolding. These structures and the metamorphism are attributed to the Grenville Orogeny.

Quartz veining of the red beds and brecciation of the adjacent gneisses, together with rotation of the dip in the red beds from gentle to vertical with increasing proximity to the contact with the gneisses in the north of the map area, indicate a fault contact with a large downthrow to the east. The rotation along this western margin does not occur where the red-bed sequence is moderately folded.

Contact Relationships

Metagabbro, metabasalt and grey quartzite (subdivisions 11a^1, 11a^2 and 11a^3, respectively) are interlayered, probably conformably, indicating that the metagabbroic rocks are probably sills. Just off the map sheet by Marie Lake, grey and red arenites (subdivisions 11a^3 and 11a^4) are conformably interlayered.

The Seal Lake Group is downthrown against and to the east of a fault contact with orthogneiss (subunit 2c) and granitoid rocks (subunits 2e/3c, 3c, 9c and 9d), and is inferred to have the same relationship with amphibolite, paragneiss and tonalitic or granodioritic gneiss (subunits 1b, 1e, 2a and 2b, respectively).

Subunit 11b: Seal Lake Group Equivalent Rocks

Breccia, red arenite and stromatolite calcirudite float.

Distribution and Subdivision

Subdivision 11b^1 occurs as a few lakeshore outcrops on the shore of Windbound Lake 10 km east of the centre of the southern edge of the map area. Subdivision 11b^2 underlies a small island just south of Vollant Lake 7.5 km south-southwest of the centre of the map area. A cluster of outcrops halfway along the northwest shore of Sail Lake, about 4 km south-southwest of the west end of Sail dyke, constitute subdivision 11b^{3}. Subdivision 11b^{4} was not found *in situ* within the map area; its presence is based on an abundance of float. (Bedrock equivalents are inferred to lie just offshore of Low's Island, 10 km west-southwest of the west end of Mackenzie Lake, along with more typical Seal Lake Group-equivalent rocks, and were probably visited by Low (1896) before the flooding of the reservoir.) These subdivisions are geographical.

Description

Subdivision 11b^{1} comprises breccia overlain by large-scale crossbedded arenite. The breccia varies from fairly dense, matrix-supported, coarse-cobble layers to bedding planes and thin layers containing scattered clasts of angular cobbles, more rounded pebbles and feldspar granules. Most breccia outcrops are poorly sorted; some coarse breccia is moderately to well sorted. Some layers are only one clast thick. Granitoid clasts of mainly local derivation (North Pole Brook Intrusive Suite, Unit 9) dominate, together with feldspar porphyry and lesser monzogranite (deformed), milky quartz, cream microgranite, quartzite, intraclastic sandstone and carbonate.

The arenite consists of sets of low-angle foreset truncations defining layers and lenses centimetres to decimetres thick, which combine to form cosets that are several metres thick (Plate 51). The cosets are bounded by higher angle truncations, and one truncation cuts down through at least 3 m of section of the underlying coset (Plate 51). The foresets consist of grain-size and colour-banded, narrow ($\leq$ 2 cm) layers, some of which are also graded. These layers are composed of pink to red, medium-grained subarkosic arenite, white to pink, coarse-grained arenite, and rare grey, very coarse-grained arenite. The feldspar component ranges from 10 to 30 percent. Quartz and the coarser grained feldspar are well rounded; finer grained feldspar is commonly subangular. Most grains are equant.

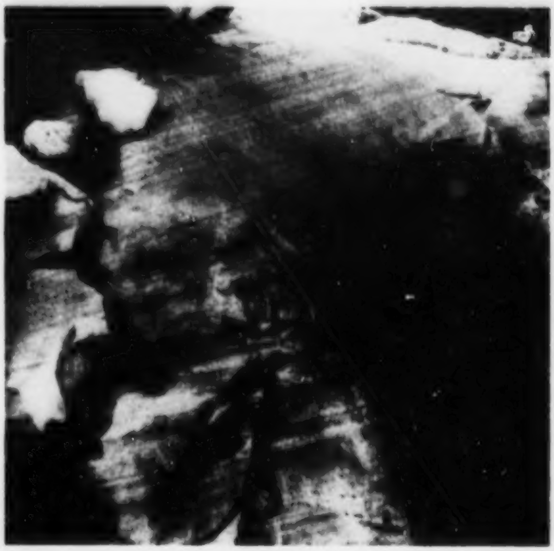


Plate 51. *Large-scale, low-angle crossbedding in red-bed arenite (subdivision 11b^{1}). Photo GN81-CS23-37, locality G487b, NTS 13L/3W, GR 7860.8352. Lower set is 1.5 m thick at right of photo.*

Subdivision 11b^{2} is a coarse (cobble to boulder) breccia dominated by clasts of red granitoid rocks. The granitoid clasts include K-feldspar-megacrystic quartz monzonite and quartz syenite, individual K-feldspar megacrysts and aplitic microgranite, all of which are typical of the local outcrops of the North Pole Brook Intrusive Suite (Unit 9). In addition, milky quartz is common and there are also rare clasts of orthogneiss, saussuritized, fine-grained, feldspathic material and possible mafic rock.

On the northwest side of the island, a granitic rock is much fractured but intact. The remainder of the outcrop constitutes fractured and dissociated granitoid rocks on all scales from boulder-size blocks (greater than 2 m) down to crystal-cleavage fragments, and all grain sizes (from boulders to silt) are involved in a chaotic, unsorted association. The clasts are mostly densely packed and subrounded to angular. Very irregularly shaped, silty lenses are present but otherwise there is not much matrix.

A 20-cm-wide, finer grained, green-matrix layer strikes eastward across the centre of the island and dips moderately south. It might be either a finer grained facies within the breccia (and represent layering in the sedimentary pile) or a clastic dyke or a fault breccia.

Subdivision 11b^{3} consists of pink-, grey- and buff-weathering polymictic breccia (Plate 52). Clasts are composed of a porphyroclastic granitoid orthogneiss, medium- to coarse-grained quartz monzonite, plagioclase-porphyritic fine-grained diorite, broken K-feldspar megacrysts, grey to milky quartz and rare red arkosic grit. The clastic matrix varies from fine grained and green to coarse grained and grey or brown; it commonly has a gritty texture. Clasts are usually either angular, or blocky and joint

Plate 52. *Breccia of porphyroclastic orthogneiss fragments in coarse matrix – possible* in situ *regolith development (subdivision 11b^{3}). Photo and locality NN81-363, NTS 13L/6W, GR 7795.2785. Diameter of lens cap is 5.5 cm.*

controlled, and are only locally subrounded. In any one place, they mostly consist of either the orthogneiss or the quartz monzonite and range up to cobble size. The maximum size of subsidiary clast types is smaller, such that K-feldspar megacrysts are less than 3 cm across and quartz clasts are generally smaller than the feldspar. Most of the rocks are very poorly sorted. The north-trending section of shoreline is parallel to fractures and shearing, and some of the smaller clast-size facies containing fine-grained, green or yellow-brown matrix relates to repeated shearing along linear zones.

Subdivision 11b^4 is not found *in situ*, but is based on a distinctive beach-rock assemblage, and is inferred to lie just offshore of Low's Island, on which the distinctive assemblage occurs. This conclusion, arrived at with some confidence because throughout the map area, the larger clast fractions in the moraines and boulder fields seem to fit closely to the local geology (i.e., down-ice dispersion haloes dissipate abruptly). Exotic rock types are found in the smaller, cobble-size fractions throughout the area, but only as a very small percentage. The progressive reduction in the abundance of red-bed boulders from the shores of Michikamau Lake (south of the Michikamau Intrusion) eastward, indicates a sizeable red-bed basin beneath the lake, perhaps similar to, or adjoining, that in the south of Michikamau Lake, to the south and southwest of the present map area (Nunn, 1981; Wardle, 1985). The concentration of large, commonly greater than 1-m-across, grey stromatolitic limestone boulders on a beach at the end of only one island in this area argues for a very local source. Therefore, subdivision 11b^4 is defined here as a discrete lithofacies and part of the Unit 11 sequence.

The most distinctive feature of this beach is the limestone clast types. Prominent amongst these are grey and more rarely brown calcareous rocks that belong to a layered sequence of calcarenite, oolitic calcarenite, columnar and hemispherical micritic stromatolites and algal-mat breccia. Rarely, the stromatolites form a continuous coating around microgranite (Plate 53) and granite cobbles and boulders similar to subunits 9h and 9g of the North Pole Brook Intrusive Suite. Also prominent are red beds (including arenite such as that in subdivision 11b^1, bright-red siltstone and fine- to medium-grained sandstone, and mudflake conglomerate), granitoid rocks typical of the North Pole Brook Intrusive Suite (subunits 9c, 9h and 9g), and smaller greenish clasts.

Petrography

The arenite from the southern shore of Windbound Lake contains grains of quartz, quartzite, chert, plagioclase, microcline, muscovite, microgranite, opaque mineral, quartz-porphyritic volcanic rock, foliated muscovite-bearing quartzite, acid-volcanic rock(?), carbonate (spar) and perthite. The grains mostly fall in the sand-size range (0.15 to 0.8 mm) and are cemented by a mixture of very fine sand and sparry carbonate. Variations in the presence or concentration of the two cement types, the degree of roundness (from subrounded to angular) and sphericity (from good to poor), grain size (within the sand-size fraction) and composition (more or less quartz and quartzite), occur on a scale of 2 to 12 mm and define the foreset laminae. The arenite is subarkosic on average.

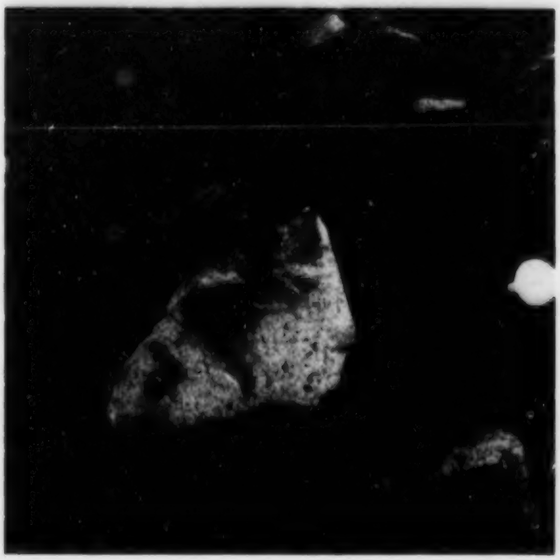


Plate 53. *Boulder of breccia, containing stromatolite-coated microgranite clasts, in beach float (subdivision 11b^4). Photo GN81-CS29-35, locality G562a, NTS 13L/4W, GR 4654.9012. Centre clast is 20 cm long.*

Structure and Metamorphism

Seal Lake Group equivalent rocks (subunit 11b) are undeformed except for the fracturing and shearing noted in the outcrops of breccia (subdivisions 11b^2 and 11b^3), which probably relate to post-depositional faulting in those areas.

Contact Relationships

The four subdivisions are not in contact. Subdivision 11b^1 was derived, at least in part, from the North Pole Brook Intrusive Suite (Unit 9) as is subdivision 11b^2, which might even be a regolith developed on top of fractured granite. Subunit 11b^3 derives its clasts primarily from orthogneiss (Sail Lake intrusive suite, Unit 2) and granitoid rocks (Units 2 and 9). Boulders within subdivision 11b^4 show that it unconformably overlay microgranite and granite typical of the North Pole Brook Intrusive Suite (subunits 9h and 9g).

PROTEROZOIC II OR YOUNGER

Diabase Dykes (Unit 12)

Definition and Division

Diabase and fine- to medium-grained gabbro dykes of Unit 12 are exposed at only a few localities in the map area.

The unit is differentiated from the diabase and amphibolite dykes that belong to subunit 2f in that they postdate the regional tectonism that affected the Archean supracrustal rocks and the Sail Lake intrusive suite (Units 1 and 2), and hence lack the high-grade deformation and metamorphic features. The dykes are either pristine or exhibit weak to strong, localized to penetrative, greenschist-facies foliations related to younger events of unknown age.

Subunit 12b is separated from subunit 12a because of its distinct petrology.

Age

The diabase dykes may be of more than one age. They postdate the Late Archean metamorphism, and most dykes also postdate the late Early Proterozoic Mackenzie Lake group and North Pole Brook Intrusive Suite (Units 8 and 9). Some dykes (perhaps all) postdate the Michikamau Intrusion (Unit 10, ca. 1460 Ma). Deformed Unit 12 dykes predate a lower-grade, greenschist-facies metamorphism. However, the age of this deformation and metamorphism is unknown.

Subunit 12a

Diabase dykes.

Distribution

The dykes intrude the following rocks: mylonite (subunit 4a) and quartz monzonite (North Pole Brook Intrusive Suite, subunit 9d) in the Naskaupi River section 5 km east of the Orma dyke; quartz monzonite (subunit 9c) on the north shore of Low's Island, 9 km west-southwest of the west end of Mackenzie Lake, and andesite and quartz monzonite (subdivision 8a^3 and subunit 9c) on a small island 3 km to the east-southeast of Low's Island; and the marginal zone of the Michikamau Intrusion (subunit 10a) on the south shore of Contact Lake (Emslie, 1970).

Description

The dykes cutting quartz monzonite (subunit 9c) on Low's Island in Michikamau Lake consist of fine-grained, green-weathering diabase. They are subvertical and trend about 170 and 020°. The dykes have chilled or tectonized margins, are plagioclase and hornblende porphyritic, are locally vesicular, and locally contain host-rock xenoliths. Tectonized margins consist of epidotized shears that locally form a breccia of angular diabase fragments in an epidote groundmass. Epidote-mineralized joints and shears also crosscut, and less commonly displace, the dykes. Epidote and amphibole fill vugs and vesicles.

On the smaller island a few kilometres to the east-southeast, a 30-cm-wide, rectiplanar, green-weathering, dark-grey diabase dyke (Plate 54) cuts quartz monzonite (subunit 9c) and the adjacent quartz monzonite-net-veined andesite (subdivision 8a^3). The dyke has a strike and dip of about 040°/65° SE.

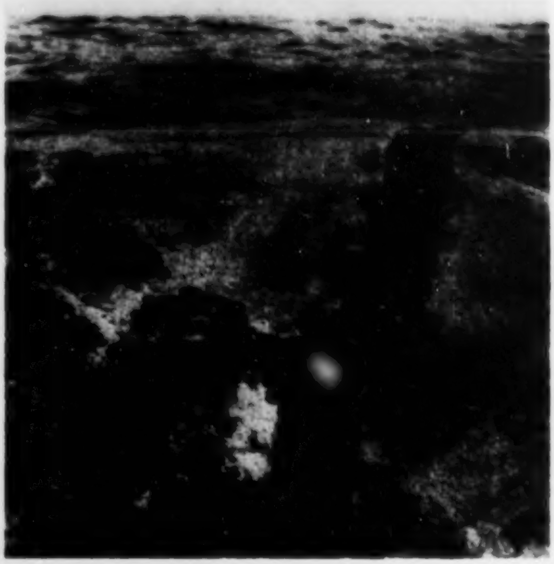


Plate 54. *Green-weathering diabase dyke (subunit 12a) cutting andesite (subdivision 8a^3, left) intruded by quartz monzonite (subunit 9c, right). Note the localized, weak dyke-parallel structure in the quartz monzonite (above and left of the hammer). Photo GN81-CS31-12, locality G575, NTS 13L/4W, GR 4935.8865. Length of hammer is 34 cm.*

In the east of the map area, two generations of subvertical diabase dykes occur in the same set of outcrops in the Naskaupi River east of Orma dyke. The younger dykes trend about 180°, cut mylonitic siltstone (subunit 4a), are recrystallized looking but undeformed, are slightly variable in thickness and are slightly sinuous. They consist of purplish-weathering, dark-grey diabase and exhibit chilled margins. The older dykes trend approximately 025°, are green-weathering, have a greenschist-facies mineralogy, and a strong, penetrative or spaced foliation. They contain porphyritic plagioclase (up to 1 mm across) in a very fine-grained green groundmass, and in undeformed augen, randomly oriented, tiny plagioclase laths. Apophyses, bayonet structures and country-rock xenoliths are still recognizable despite the deformation, which is commonly concentrated along the margins of the dykes. Internal deformation in the dykes is heterogeneous and cleavage refraction occurs between more or less-deformed lithons in the dyke as well as between dyke and country rock. The dykes are preferentially deformed relative to their hosts. Undeformed dyke margins are chilled. The dykes cut flaggy siltstone (subunit 4a) and quartz monzonite (subunit 9d) and also follow the siltstone–quartz monzonite contact.

The dyke intruding the marginal zone of the Michikamau Intrusion in the Contact Lake area is known only as a 'small diabase dyke' (reported by Emslie, 1970).

Structure and Metamorphism

The dykes vary from undeformed to penetratively cleaved, and from pristine to greenschists. Epidotization is widespread in association with the foliations. Despite the varying directions and intensities of foliation in the river east of Orma dyke, all the fabrics seem to relate to the mylonite zone that is of similar (approximately 165°) trend a few tens of metres to the west. The age of the mylonite zone is unknown. No earlier or later structures are known from either the dykes or the host rocks.

Contact Relationships

Subunit 12a cuts subunits or subdivisions of Units 4, 8, 9 and 10 (see above).

Subunit 12b

Plagioclase-megacrystic diabase dykes.

Distribution

Subunit 12b occurs along the north shore of the peninsula underlain by hypabyssal andesite (subdivision 8a^1) near the southwest corner of the map area.

Description

Subunit 12b is a swarm of dykes dipping subvertically north or south and trending approximately 060°. The dykes are commonly very sinuous and vary in width from 2 cm to over 4 m. They contain chilled margins, apophyses, bayonets and other offsets.

Many of the dykes are strikingly plagioclase megacrystic (Plate 55). Megacryst size ranges between 1 and 40 cm (commonly 10 to 15 cm). The larger megacrysts contain both crystal faces and broken sides and are rounded at the corners; small megacrysts are either fragments of larger crystals or complete euhedra. The megacrysts exhibit heterogeneous presence and size distribution. Commonly they are concentrated toward the centres of the dykes and size generally decreases as the dykes narrow. Locally, however, larger-than-usual megacrysts are wedged across the full width of an offshoot or a dyke termination. Megacryst size changes along the length of some dykes, even where the dyke width is constant.

The plagioclase megacrysts show evidence of disequilibrium. Some are internally veined by plagioclase that cuts across the cleavage in the host feldspar. Similarly, many megacrysts are corroded by the dyke groundmass, which pervades the crystal margins and the cleavage, and locally almost net-veins the megacryst. In addition, acicular bundles of black hornblende have nucleated at megacryst–groundmass interfaces and grown into the plagioclase, probably replacing it in the solid state. These bundles are up to several centimetres long. The megacrysts may be either xenocrysts or high-pressure cognate minerals that may or may not be phenocrysts of the diabase groundmass.

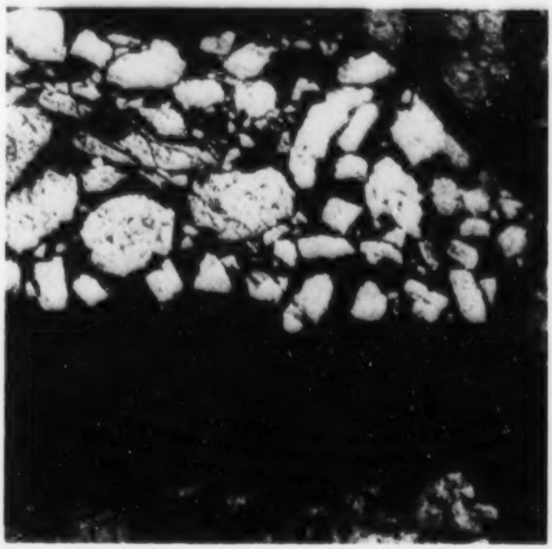


Plate 55. *Plagioclase-megacrystic diabase dyke (subunit 12b) – note zonal presence of megacrysts. Photo GN81-CS32-17, locality G598b, NTS 13L/4W, GR 4845.9236. Length of hammer head is 17.5 cm.*

The groundmass to the megacrysts has a coarse diabase texture. Narrow dykes are fine grained or aphanitic. The groundmass also encloses green to black, ferromagnesian (pyroxene?) phenocrysts, mostly of 1 to 4 mm but up to 2.5 cm in diameter. Most of these phenocrysts are equant and partly rounded; less commonly they are subhedral and some of the larger ones are 'broken'. They are scattered or distributed in layers. Pyrite is a rare accessory phase. Locally, the diabase is strongly epidotized.

Structure and Metamorphism

During emplacement the dykes were back-veined. Dyke sinuosity is also assumed to be an original feature. Probably the first feature to affect the dykes after emplacement was the growth of the hornblende bundles, which is most likely the result of a subsolidus disequilibrium that occurred during cooling. Later effects consist of alteration, epidotization, brittle fracturing and displacement of the dykes and their apophyses.

Contact Relationships

The dykes of subunit 12b cut subvolcanic porphyry (Mackenzie Lake group, subdivision 8a^1) and microgranite (North Pole Brook Intrusive Suite, subunit 9h).

PLEISTOCENE

Surficial Deposits (Unit 13)

Till, outwash, lacustrine and possible deltaic or fluvial deposits.

Definition and Division

Surficial deposits occur throughout the map area. The deposits commonly form a discontinuous veneer (<1.5 m thick) over areas of undulating or hilly relief, but can be exposed as continuous blankets (>1.5 m thick) over the bedrock geology. Where the drift topography is relatively flat and the relief of the drift basement interface unknown, pockets of drift of considerable thickness may be present.

Surficial sediments are divided into till, glaciofluvial sediment, and lacustrine and related deposits. Their distribution on the map is, for the most part, generalized. Figure 12 is a compilation of the surficial sediments and their major morphological features.

Age

The surficial deposits are assumed to be Quaternary in age.

Subunit 13a

Till.

Distribution

Till is exposed across the whole of the map area, except for an outwash plain (possibly sandy till) in the centre-north part of the area and the eskers (see below). Only two or three small areas of several square kilometres, underlain by leucotroctolite (subdivision $10b^2$), can be classified as predominantly barren; most major bedrock outcrops in the map area are less than 1 km across.

Description

Till forms a discontinuous veneer or thin blanket throughout most of the hilly country, especially along the hillsides, but also across the tops of many hills and ridges. In the valleys, thicker deposits form up to 4.5 km wide, easterly oriented, linear belts of ribbed moraine and hummocky terrain. There is a large area (approximately 300 km^2) between Fraser, Sail and Kasheshibaw lakes of gently undulating country, comprised of bog and spruce-covered hummocks and ridges, that is covered by till of unknown thickness.

Glacially moulded linear ridges (flutes, Figure 12) are not an especially prominent feature of the map area (as they are in many parts of central and southern Labrador). Mostly, they occur in areas of gently undulating, subdued relief. The longest flutes occur between Fraser and Kasheshibaw lakes and are up to 3.4 km in length. Some areas, e.g., northeast of Duck Bay, are characterized by a multitude of small flutes (up to 600 m long). Drumlinoid ridges and crag-and-tail landforms comprise similar, linear, morphological features. Though generally of shorter length than the larger flutes these features locally attain lengths of 3 km. Drumlinoid forms are most abundant north of central Kasheshibaw Lake, whereas the crag-and-tail landforms are most common around Connecting Lake and across the marginal zone of the Michikamau Intrusion (Unit 10). In these areas, the crags are predominantly underlain by quartz syenite and quartz monzonite (North Pole Brook Intrusive Suite, subunits 9e and 9d), and by leucotroctolite (Michikamau Intrusion, subdivision $10b^2$), respectively. Related glacial lineations consist of roches moutonées and striae, the former widely scattered but not common, the latter most abundant on lakeshore outcrops of quartz monzonite (subunit 9d) in Orma and Fremont lakes.

All five linear features are associated, occur in the same areas (not in areas of hummocky terrain or ribbed moraine), relate to periods of ice advance, and are mostly subparallel in any one area. Trends vary from toward the east-southeast to toward the east-northeast and, where unidirectional, demonstrate a generally eastward ice flow. However, in detail, several types of discordance are evident. A line of convergence trends east-northeasterly across the map area from Windy Bay to Desolation Lake and separates, in the northern part of the map area, east-southeast-trending lineations (northwest quadrant) and easterly trending lineations (northeast quadrant), from, in the southern part of the map area, east-trending lineations (southern third of the map area) and east-northeasterly trending lineations (in the triangle between Vollant, Orma and Desolation lakes). In addition, easterly, and northeasterly to east-northeast-trending flutes overlap in the areas north and northeast of Vollant Lake and northwest and east of the north end of the Orma dyke. These two trends actually crosscut one another north of Vollant Lake and east of the Orma dyke. In these cases, the 'finer' fluting trends east-northeast and is interpreted to be the younger of the two.

In the northeast of the map area, where tributaries of the Kanairiktok River have cut through the till cover and incised into the subhorizontal Seal Lake Group red beds in a series of steep gorges, the tops of the gorges reveal 50 m or more of till. The intervening spurs have a relief in till of at least 20 to 30 m and thus till sections in this area may well exceed 100 m thick.

Several good exposures of till along hillsides have resulted from flooding of the reservoir. The till is very poorly sorted to unsorted and contains angular, commonly brown-coated clasts varying in size from pebbles to boulders greater than 1 m in diameter. The latter commonly occur on or near the bedrock surface. The sediment is matrix supported by a dark-brown, silty-sand that is weakly indurated and commonly exhibits a pronounced, undulating, subhorizontal fissility.

Contact Relationships

The till is unconformable on all other units. In places till has been eroded or carved into terraces by glaciofluvial meltwaters associated with subunit 13b.

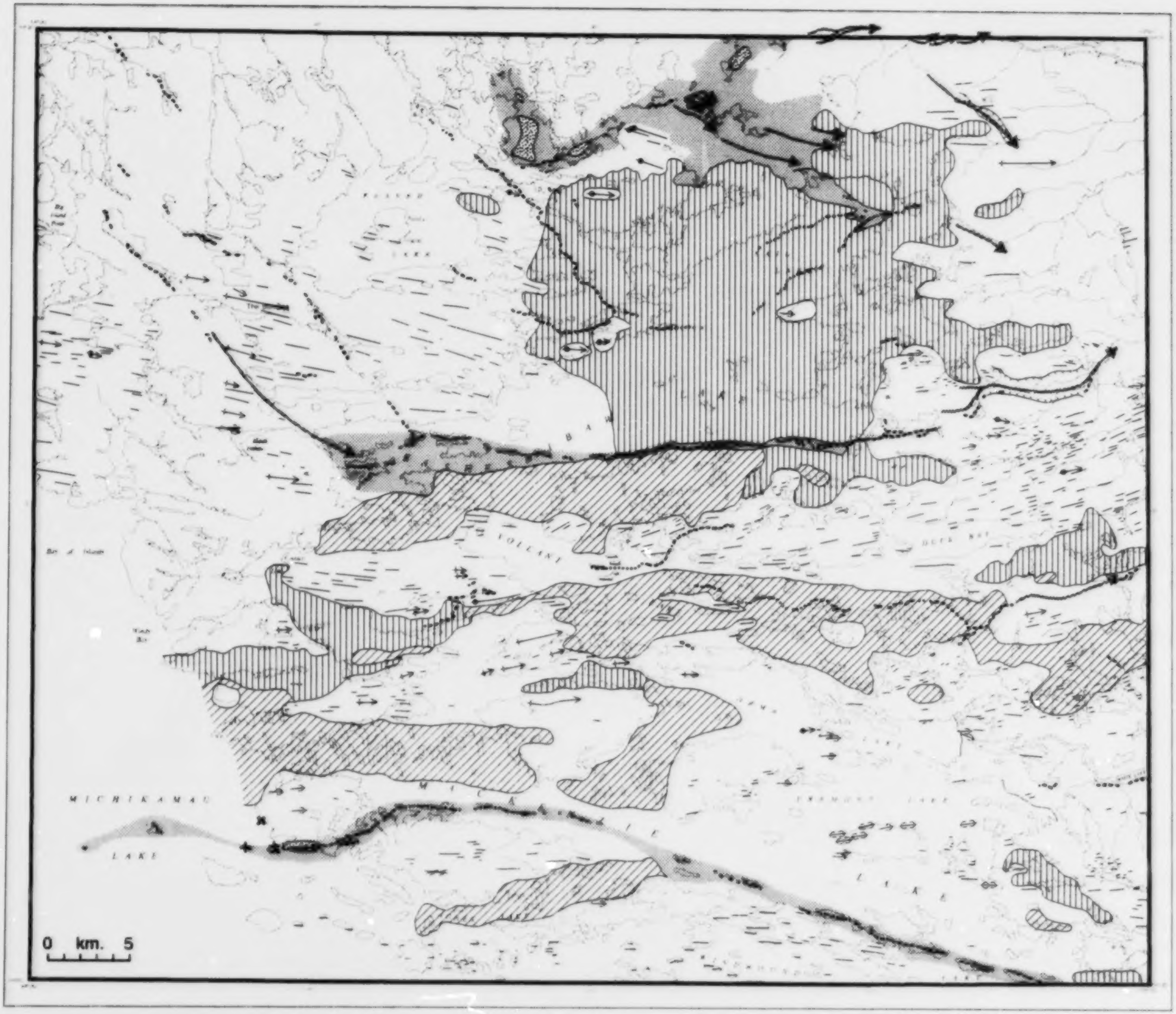

MICHIKAMAU
LAKE
VOLLANT
0 km. 5

Figure 12. *Glacial, glaciofluvial and lacustrine features of the northeastern Smallwood Reservoir map area.*

LEGEND (Figure 12)

Glacial lineations
- *–fluting*
- *–crag-and-tail*
- *–drumlinoid features*
- *–roche moutonée*
- *–striae (directional, non-directional)*

Ribbed moraine belts
Hummocky terrain
Outwash or sandy till
Areas of abundant kettle holes
Eskers (submerged)
Major spillways (meltwater channels)
Partly abandoned paleodrainage patterns
+ *Fluvial or deltaic sands*
× *Raised beach*

Subunit 13b

Outwash and eskers.

Distribution

The main area of this subunit occurs in the north of the map area in a 60 km², irregular, easterly-oriented belt of outwash, up to 6 km wide, stretching from the north of Fraser Lake to the west end of the Sail dyke. The other main parts of the subunit are eskers and the narrow, terraced outwash aprons that commonly fringe them. The two main esker systems are the east-southeast-trending Mackenzie Lake esker that skirts the southern margin of Mackenzie Lake, and the east-trending Kasheshibaw Lake esker that is found within, or along the southern shore of, Kasheshibaw Lake. Several smaller, similarly oriented eskers occur between and north of these two, except in the northwest quadrant of the map area where southeasterly-trending eskers in the Fraser Lake region join the Kasheshibaw and Sail Lake esker systems in Kasheshibaw Lake.

Description

The eskers form narrow, sinuous ridges, mostly less than 200 m across and up to 30 m high. In general, they contain moderately well-sorted, rounded to subrounded pebbles to small boulders, which vary from scattered to densely packed. The matrix is subangular to angular, poorly sorted material that fines down to coarse sand. In their western exposures, both the Kasheshibaw Lake and the Mackenzie Lake eskers occur as multiple ridges.

Terraced outwash aprons fringe the eskers in places. They are up to 0.5 km wide and dominated by sand.

The large outwash plain in the north is also sand dominated and is gently undulating in general relief. Streams are commonly incised into the plain. Both the plain and the terraced aprons locally contain abundant kettle holes.

Contact Relationships

Outwash and eskers unconformably overlie all other units. Glaciofluvial systems responsible for producing subunit 13b are thought to have formed terraces in outwash and in ribbed moraine, at least locally, for example, where the Mackenzie Lake esker system passes from Michikamau Lake east to Mackenzie Lake.

Subunit 13c

Raised beach and possible fluvial or deltaic sands.

Distribution

The raised beach occurs near the western tip of the island containing most of the Mackenzie Lake group (Unit 8) outcrop area near the southwestern corner of the map area. The sands occur at water level at the base of the glaciofluvial terraces cut into outwash near where the Mackenzie Lake esker system leaves Michikamau Lake.

Description

The raised beach forms a flat bench of well-sorted, moderately rounded boulders (Plate 56) and is about 8 m above the present maximum reservoir level.

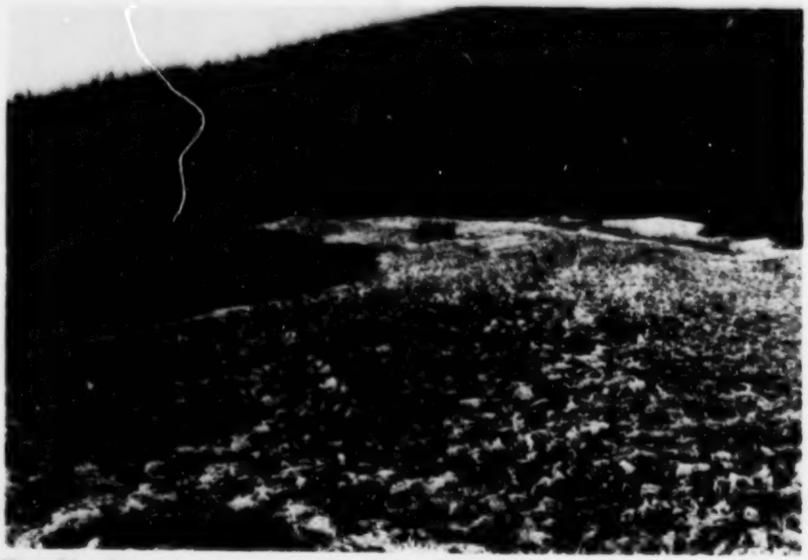


Plate 56. *Raised beach (subunit 13c). Photo GN81-CS32-11, taken looking north from locality G595b, NTS 13L/4W, GR 4805.9326.*

The sands were noted in two places near the present level of Michikamau Lake, at the base of low terraces eroded in outwash. These deposits consist of cemented, yellow-brown and dark-brown, friable, angular, medium- to coarse-grained sand containing thin (centimetre-scale) beds and flat lenses of poorly sorted granule gravel.

Contact Relationships

The cemented sands appear to be overlain by outwash (subunit 13b) but may have been deposited into erosional features cut laterally into the outwash (personal communication, Martin Batterson, October 1992).

DEPOSITIONAL AND TECTONIC HISTORY

INTERPRETATION OF DEPOSITIONAL ENVIRONMENTS

Introduction

The supracrustal rocks (Unit 1), the arkosic metasedimentary rocks (Unit 4) and the Petscapiskau Group (Unit 5) occur within the Archean and possible Early Proterozoic rock association. The supracrustal rocks (Unit 1) are an Archean marine sequence. The arkosic metasedimentary rocks are possibly a terrigenous top to the Archean supracrustal succession and of similar age, or may be a younger continental clastic succession. The Petscapiskau Group is another marine sequence that contains broadly similar lithotypes, facies variations and environments to the Archean supracrustal rocks. The possibility that the two are equivalent and that the Petscapiskau Group is also Archean has been alluded to earlier (page ?). However, it has also been noted that the Petscapiskau Group may be a cover sequence to the Sail Lake intrusive suite (Unit 2 Archean orthogneiss), as opposed to intruded by it, which is the case for Unit 1. Should some, or all, of the arkosic metasedimentary rocks or the Petscapiskau Group (Units 4 and 5, respectively) be significantly younger than the Archean supracrustal rocks (Unit 1), their minimum age is Early Proterozoic.

The Mackenzie Lake group (Unit 8) is a late Early Proterozoic continental clastic and volcanic sequence associated with the Trans-Labrador batholith (North Pole Brook Intrusive Suite, Unit 9) of the late Early Proterozoic rock association. The Seal Lake Group (Unit 11) is a continental red-bed cover sequence from the Middle Proterozoic rock association, and Unit 13 comprises the surficial deposits related to the Wisconsinan glaciation.

Archean Supracrustal Rocks (Unit 1)

The supracrustal rocks consist of massive and layered amphibolite (subunit 1a), mainly derived from pillow lava and related rocks; intergranular- and cumulate-textured metagabbro (subunit 1b); pelitic paragneiss (subunit 1f); thin-bedded, siliceous, pelitic and tuffaceous sedimentary rocks associated with porphyritic tuffs, felsic pillow lava and polymictic conglomerate (subunit 1d); quartzite (subunit 1g); thick sheets of diatexite containing screens of paragneiss (subunit 1e); and minor ultramafic rock (subunit 1c). The intergranular gabbros are mostly stocks and crosscutting intrusions in the pillow-lava sequence, and the cumulate gabbros probably occur as sills. The diatexite is probably derived from pelitic to semipelitic paragneiss similar to the screens or subunit 1f.

Several 'associations' are present within this supracrustal sequence. Intergranular gabbro (part of subunit 1b), for example, occurs only with amphibolite (subunit 1a). Subunit 1d metasedimentary and volcanic rocks and subunit 1g quartzite are intimately intercalated with the amphibolite (subunit 1a) in the south and central outcrop areas. In the northern outcrop area, cumulate gabbro (part of subunit 1b) is interlayered with amphibolite (subunit 1a), diatexite and paragneiss (subunit 1e) and orthogneiss (Unit 2). Pelitic paragneiss (subunit 1f) locally appears in sequence with quartz-rich metasedimentary rock (subunit 1g) and amphibolite (subunit 1a), and, in and east of Kasheshibaw Lake, the pelite contains thin quartzitic and psammitic intercalations typical of subunits 1g and 1d.

Way-up features are rare within the sequence. Mostly, they consist of pillow-facing directions, along with minor rhythmic compositional variations in cumulate gabbro and cross lamination in the quartzite. Although minor and map-scale isoclinal folds occur, most younging directions are consistently to the east. If this is a reflection of the overall stratigraphy and not an artifact of the limited number of readings, it indicates that, in the central area, the quartzite occurs low in the exposed sequence of amphibolite, whereas the felsic volcanic, tuffaceous and thinly bedded metasedimentary rocks (subunit 1d) occur toward the middle and top of the sequence (this subunit could be fold repeated). In the southern area, subunit 1d occurs with, and as subsidiary layers throughout, the amphibolite. No younging directions were recorded in the northern area.

The volcaniclastic, feldspathic and generally immature nature of the conglomerate and metasedimentary rocks in subunit 1d indicates proximal derivation from a volcanic provenance. Crossbedding in the quartzite (subunit 1g) shows that this subunit is a current-deposited clastic rock and not a recrystallized chemical precipitate, and that it probably represents shallow-water reworking. Interlayering of quartzite (subunit 1g) and proximal clastic rocks (parts of subunit 1d) with the mafic volcanic rocks (subunit 1a) indicates that the pillow lavas are shallow-water, rather than deep-water, volcanic rocks. The predominance of fine grained (subunits 1e and 1f) or immature volcaniclastic (subunit 1d) rocks in the sediments associated with the mafic volcanic rocks indicates a restricted and generally local sediment supply adjacent to a volcanic edifice. The general lithological association suggests a marine environment. Preliminary geochemical analyses of the mafic volcanic rocks (subunit 1a; N. Noel, personal communication, February, 1991) give a tholeiitic affinity, indicating an oceanic or island arc, or a mature rift (ocean formation).

The distribution of rock types may indicate deepening toward the north and/or progression away from the volcanic centre (present configuration). If the migmatitic arkosic arenite of subunit 4a is part of the Unit 1 sequence, this potential depth variation may be reinforced, and would further indicate a shallowing-upward sequence and transition into a continental environment in an eastward or southeastward direction. In addition, if the structural and metamorphic culmination in the north is also a right-way-up stratigraphic culmination, it indicates that mafic and pelitic rocks containing gabbro sills underlie the main mafic volcanic sequence.

Arkosic Metasedimentary Rocks (Unit 4)

Exposures of arkosic metasedimentary rocks are sparse, confined to NTS map area 13L/3 east, and not necessarily all of the same age. The outcrop areas are separated and of unknown relationship to each other. The two recorded younging directions face east, and occur in the area about 5 km south of Marie Lake.

Arkosic arenite of subunit 4a is rich in microcline and probably was derived from continental crust that was, at least partly, granitic or syenitic. A subaerial or terrigenous environment of deposition is indicated by the prevalence of, locally crossbedded, arkosic arenites.

In places, subunit 4a is migmatized. Within the map area, the only supracrustal unit to undergo dynamothermal migmatization was Unit 1 and only one age of migmatization has been confirmed (Nunn *et al.*, 1990). Unit 1 also consistently youngs eastward. These pieces of structural evidence suggest that the migmatitic rocks might be equivalent to Unit 1 and therefore be Archean. However, the rocks form a red- and pink-weathering sequence and red beds do not occur in Archean sequences (due to a lack of oxygen in the atmosphere with which to oxidize iron) unless the reddening is secondary. (It is not known if this is the case here; however, hand-specimen examination by Tomasz Dec (personal communication, November, 1991) indicates that the colour is a result of the metamorphism of feldspar.) Non-migmatitic parts of subunit 4a (the Naskaupi River occurrence) may be a younger sequence or mylonitized microgranite (see subunit 4a, petrography).

The only known possible source within the map area of the clasts in the quartzite-cobble conglomerate (subunit 4b) is the quartzite (subunit 1g). The matrix is a micaceous psammite and probably derived from a muddy arenite. The rock could be derived from, or be a part of, the Archean supracrustal sequence (Unit 1).

Subunit 4c is a micaceous schist. It could have been formed in any pelite-protolith environment.

Petscapiskau Group (Unit 5)

The Petscapiskau Group consists of mafic metavolcanic rocks (subunit 5a), pelite (subunit 5f), psammite and quartzite (subunit 5e), rhyolite-porphyry conglomerate (subunit 5c), metagreywacke (subunit 5d), minor metagabbro (subunit 5b), and their contact metamorphic equivalents. The large area of poorly exposed pelite in the northern part of the lobe southeast of the Michikamau Intrusion (Unit 10) is inferred to be subunit 5f. Metagreywacke (subunit 5d) may represent a facies variant of the pelite (subunit 5f) or the conglomerate (subunit 5c) in this area. South of the pelite, the conglomerate is interdigitated with mafic volcanic rocks (subunit 5a) near the contact between subunits 5a and 5c. However, it is not known if the felsic volcanic rocks that make up the clasts in the conglomerate are coeval with the sequence or derived from older rocks. Mafic volcanic rocks occur only south of Hook Lake and the rhyolite-porphyry conglomerate occurs only in the lobe.

The remaining clastic rocks are associated and exhibit a facies change. In the southern part of the map area, thick sequences of clean quartzite and arenite are seen to contain thin pelitic laminae (subunit 5e). Farther north, around Contact Lake, pelite forms thicker layers such that pelite, quartzite and psammite are all interbedded in the generally coarser parts of the succession. Quartzite peters out between Contact Lake and The Buttress, and in the north (Fraser Lake), pelite units (subunit 5f) are interlayered with an interbedded psammite and pelite facies (subunit 5ef).

Way-up data were not observed in the northern areas. Those in the south indicate that the antiform coring the lobe is right way up, and that the sequence is southward- and westward-younging, passing up from pelite, through rhyolite-porphyry conglomerate and pillow lava, into interbedded facies and quartzite; this is the southern part of the clastic facies variation noted above. The information comes from pillow facing directions in the mafic volcanic rocks, graded bedding in the conglomerate and crossbedding in the quartzite and thin psammitic layers. Reversals of younging occur due to tight to isoclinal minor folds observed up to outcrop scale. If any of the subunits or layers internally contain a regional fold trace, such an isoclinal repetition of the succession would require major facies changes across this regional fold axial trace.

The hinge-line sequence up through the antiform in the lobe (pelite–conglomerate–pillow lava–interbedded facies–quartzite) may represent either consistently shallow water with a restricted sediment supply at the outset, or a shallowing-upward succession. Above the volcanic rocks in the south, the abundance of clean quartzite, arenite and localized mature conglomerate indicate reworking and winnowing in a shallow-water environment. The facies changes suggest passage northward into a more distal and perhaps deeper water environment. The sequence as a whole indicates a marine environment.

The pillow lavas are tholeiitic (N. Noel, personal communication, February, 1991) and may represent an oceanic or mature-rift environment, although the sedimentary rocks indicate that this would probably have occurred at a continental margin or adjacent to an arc. The abrupt variations in clast size within the rhyoiite-porphyry conglomerate (subunit 5c) imply that the coarser areas are very proximal, and the outcrop-size 'clast' (more than 3 m across) occurring near the western end of the subunit may in fact be at, or a part of, the source. The relationships suggest either a clastic wedge derived off of a syndepositional scarp, or a clastic apron that was deposited around a syndepositional volcanic edifice (the scarp would be part of the basement, which could range from something only slightly older to something much older: the volcanic edifice would represent coeval felsic volcanism). The microgranite clasts in the conglomerate are probably related to the rhyolite porphyry at source; the mafic clasts are probably local and derived from initiation of the mafic volcanism that succeeds the porphyry. Locally, mafic volcanic rocks are interdigitated with the conglomerate near this contact.

Mackenzie Lake Group (Unit 8)

The Mackenzie Lake group comprises acid to intermediate volcanic rocks (subunit 8a) and red and grey sandstones (subunit 8b). The volcanic rocks occur to the west of Mackenzie Lake; the sandstones are present northwest of the west end of the lake and northeast of the east end of the lake. Both subunits occur as enclaves in the North Pole Brook Intrusive Suite (Unit 9) in Vollant Lake. The intermediate volcanic rocks are andesitic (subdivisions 8a^{1,2,3,5}) and the more acidic layer is a fine-grained, quartz- and plagioclase-porphyritic, dacitic rock (subdivision 8a^{4}) that occurs within the andesite sequence. Petrological and mineralogical transitional features between the andesites and the dacite indicate a genetic relationship between the two. The sandstones are interpreted as terrigenous clastic rocks deposited in a fluviatile environment (cf. Walker and Cant, 1984). Northwest of Mackenzie Lake, the eastern outcrop probably represents a sand-bar sequence and the western outcrop overbank deposition (*op. cit.*), although exposures are limited.

A uranium–lead date on a hypabyssal variety of the andesitic rocks (subdivision 8a^{1}) yielded an age of 1651 ± 3 Ma (Krogh, 1985). This is not significantly different from dates determined on the Trans-Labrador batholith (Nunn *et al.*, 1985), which intrudes the Mackenzie Lake group. The group is interpreted to represent a coeval volcanic and clastic carapace to the batholith, which, on a regional scale, is primarily of granitoid composition and elongate in form. The Mackenzie Lake group and the batholith probably represent the major components of a continental arc.

Seal Lake Group and Equivalent Rocks (Unit 11)

The Seal Lake Group (subunit 11a) occurs at the eastern margin of the map area where it consists of, from north to south, red arenite and fine-grained conglomerate (subdivision 11a^{4}), red arenite (subdivision 11a^{4}), grey arenite (subdivision 11a^{3}), and interlayered basalt, grey arenite and gabbro (subdivisions 11a^{2}, 11a^{3} and 11a^{1}). The grey arenaceous rocks only occur south of Marie Lake. The gabbro forms sills. Mafic volcanic rocks (e.g., subunit 11a^{5}) interlayered in the red-bed sequence only occur in the northeastern corner of the map area but do occur within this sequence immediately to the east, where, also, gabbro sills occur throughout much of the succession (Brummer and Mann, 1961). Basic volcanism is clearly intimately associated with the sedimentary rocks in the Seal Lake Group.

To the east of the map area, Roy and Fahrig (1973) and Baragar (1981) investigated the basic rocks and found the flows and the sills to be a homogeneous sequence of olivine basalt and dolerite, transitional between tholeiite and alkali basalt. Baragar (*op. cit.*) compared them with plateau basalts and contrasted them to basalts of oceanic affinity, such as those in the Labrador Trough. The geochemical characteristics of the volcanic rocks and their association with continental sedimentary rocks have prompted most authors to equate the Seal Lake Group with continental rifting and to place it in a regional, anorogenic setting. The anorogenic setting was formerly assumed to be relatively continuous for most of the Middle Proterozoic in southeastern Laurentia (ca. 1600 to 1100 Ma; Baragar, 1981) and to be broadly divisible into an earlier magmatic event, manifested by anorthositic-granitoid suites and mafic intrusions (Emslie, 1978a, b; Gower *et al.*, 1990a), and a later rifting event, characterized by terrestrial sedimentation and basaltic and peralkaline volcanic activity (Emslie, 1978b; Hill and Thomas, 1983). Refinement of the Middle Proterozoic history of Nena (i.e., Laurentia and Baltica, Gower *et al.*, 1990b) has permitted the anorogenic period to be more carefully divided into stages, which are summarized by Gower *et al.* (1990c). The stage that includes the Seal Lake Group ranges from ca. 1410 to ca. 1250 Ma in Labrador/Quebec and includes mafic and felsic varieties of both volcanism and plutonism as well as continental sedimentation (Gower *et al.*, 1990c).

Fahrig (1957) states that the Seal Lake Group 'apparently' formed on an area of continental crust and represents 'continental to epicontinental marine deposition', an hypothesis echoed by Knight (1972), Roy and Fahrig (1973) and this study. Paleomagnetic work on the Seal Lake Group red beds and volcanic rocks (Roy and Fahrig, 1973; Park and Roy, 1979) indicates tropical to subtropical latitudes (5 to 20°) during formation of the group, and thus a climatic zone in keeping with an oxidizing environment and red-bed deposition.

Red beds contiguous with the main Seal Lake Group basin occur in a wedge-shaped area down the eastern margin of the map area (subunit 11a). In the north of this wedge-shaped area, conglomerate ± sandstone is interpreted as a mixed alluvial sequence of distal fanglomerate or braidplain, sandstone and minor conglomerate is interpreted as sandy braided-stream deposits and deep-red, muddy sandstone is interpreted as minor overbank or end of flood-stage deposition (cf. Steel, 1974; Cant and Walker, 1978 and Rust and Koster, 1984). Farther south (near Desolation Lake), the red arenite is interpreted to be a stack of fluviatile sand bars in an alluvial plain (cf. Allen, 1983; Walker and Cant, 1984). The grey arenite south of Marie Lake may indicate that a transition has occurred from subaerial to shallow-marine deposition; hints of pillow structures in interlayered basalt may support this.

Current indicators in the red beds give directions ranging toward the southeast to the southwest; overall facies changes also occur in this direction. These data indicate a source to the north and facies variations that are independent of the bounding faults to the west, and further imply that deposition pre-dated, and was not controlled by, faulting, or that paleocurrents were longitudinal along a fault-bounded basin (cf. Steel, 1976; Steel *et al.*, 1977). However, coarser conglomerate commonly occurs close to the bounding faults where the rocks are upturned due to drag on the faults. These are deeper in the sequence and imply a fining-upward succession. Simple graphic reconstruction of the upturned red beds also shows that in this area the sequence is a minimum of 3 km thick. Farther east, Mann (1959) and Baragar (1981) estimate a total thickness for the Seal Lake Group in excess of 9 km.

The Seal Lake Group equivalents (subunit 11b) are scattered throughout the remainder of the map area as isolated occurrences (see Map 93-19). They are mainly coarse-grained clastic rocks composed of cobble to boulder breccia and conglomerate (subdivisions 11b^{1,2,3}), red arenite (subdivision 11b^{1}), and a unique stromatolite–calcarenite–breccia float (subdivision 11b^{4}). The coarser grained facies contain clasts that are strongly representative of rocks from the local area, or are typical of the Trans-Labrador batholith or similar rock types. They are interpreted to represent rocks formed at or very close to an unconformity. The impression that parts of clasts would fit back together if thin veneers of matrix were removed, is consistent with generation of a regolith above fractured bedrock, but might also represent a tectonic origin for (some of) these rocks. The arenite at the centre of the map area's southern edge (subdivision 11b^{1}) represents passage upward from breccia into typical alluvial Seal Lake Group-type rocks (crossbedded arenite). Just south of the map area, this trend is continued in a series of several fining-upward alluvial cycles topped by shale (Nunn, 1982).

The unique float contains stromatolite-coated granite cobbles. (The granite resembles some lithotypes in the Trans-Labrador batholith.) Much of the remainder of the primary calcareous assemblage (calcarenite, algal-mat breccia and stromatolite mounds up to a metre or more thick) is consistent with a littoral environment. The size and lack of break up of some clasts, which include breccia of stromatolite-coated granite, indicate minimal transport of the float. Also, Low (1896) recorded an *in situ* 'bluish-grey (Cambrian) limestone' facies resting on granite from this map area and blocks of 'highly contorted rock' exhibiting 'the appearance of organic structure similar to that of stromatopera' (*ibid.*, page 281) to the south. The former locality is given as about 12 km south of the southern end of the Michikamau Intrusion in Emslie (1970) and coincides with the location of the unusual float but, presumably, is below the present water level. Similar rocks have been recorded from the main Seal Lake Group area east of the map area (Mann, 1959; Brummer and Mann, 1961) and for these reasons, and its association with abundant red arenite clasts, the float is thought to represent a Seal Lake Group environment.

Pleistocene (Unit 13)

The regional till cover (subunit 13a) and the eskers and outwash (subunit 13b) are clearly related to glacial processes. These are known from throughout much of the northern hemisphere and are bracketed by ^{14}C dates and fossil evidence as Late Wisconsinan (see Vincent, 1989). Striae, grooves and ice-sculptured features, such as flutes, roches moutonées and crag-and-tail ridges, consistently trend between 075 and 120°, have a mean at 090° ± 5°, and, where unidirectional, define a generally eastward ice flow. The eskers indicate an eastward flow to meltwater throughout most of the map area. The easterly trend forms a trunk system to a subsidiary southeasterly trend in the northwestern quadrant of the map area.

It is assumed that the raised beach (subunit 13c) could not have survived the passage of an ice sheet and that it postdates the last major glaciation of the region. The beach probably relates to a proglacial lakeshore established early in the most recent deglaciation of the area. The height of land at this time probably formed a watershed south and east of the present Labrador–Quebec border that may have been characterized by relict, elongate mountain ice caps (Vincent, 1989). Drainage within the map area would have been approximately northwestward toward the George River and the proglacial lake may have ponded against ice retreating northward down the George River system towards Ungava Bay. Subsequent drainage reversal in the region was caused by greater isostatic uplift northwest of the map area, where the ice sheet was thicker, than within the map area itself (Liverman and Vatcher, 1993). There is abundant evidence of drainage reversals recorded in the drainage patterns of central and western Labrador. Given the elevation of the raised-beach relict, much of western Labrador between Michikamau Lake and Schefferville, and extending southward an unknown distance, could have been occupied by a proglacial lake at this time (David Liverman, personal communication, June, 1991).

The cemented sand and gravel in subunit 13c are friable but coherently bedded. They possess a similar degree of induration to some of the compacted till in the map area, and are thus designated as Pleistocene. They probably relate to deltaic or fluvial sedimentation associated with the proglacial lake or with subunit 13b, and may have been cemented as a result of groundwater activity (Martin Batterson, personal communication, November, 1992). The occurrence of these sediments a little below the height of the raised beach, and their distribution, close to the present water level, around the shores of Michikamau Lake in this area and that to the south (unless fortuitous), suggests deposition during a high water-level stand in the Michikamau Lake basin at about 480 m above sea level. (Michikamau Lake has been artificially raised approximately 13 m to its present maximum level of about 473 m.)

STRUCTURE AND METAMORPHISM

Introduction

The map area spans the boundary of the Rae (part of the eastern Churchill Province) and Grenville provinces (Figure 4). By definition, the Churchill Province was affected by the Hudsonian Orogeny at ca. 1800 Ma and the Grenville Province was affected by the Grenvillian Orogeny at ca. 1000 Ma (Stockwell, 1961, 1963a, 1964, 1973, 1982). The Rae Province contains Archean gneisses that were variably reworked during the Hudsonian Orogeny (Hoffman, 1989), and the northern part of the Grenville Province contains the Labrador Orogen (Thomas *et al.*, 1985, 1986; Wardle *et al.*, 1986). The author interprets field work (Nunn and Noel, 1982) and U−Pb dating (Krogh, 1983, 1985; Brooks, 1983) to indicate late Early Proterozoic or early Middle Proterozoic synplutonic structures, and further U−Pb age determinations (Nunn *et al.*, 1990) indicate lead loss at a similar time. The last (*op. cit.*) also demonstrates Archean orogenesis. Accordingly, structural and metamorphic events within the map area may relate to one of at least four orogenic events, namely late Archean (2700 to 2500 Ma), Hudsonian (1870 to 1770 Ma), Labradorian (1710 to 1620 Ma) or younger, and Grenvillian (1150 to 950 Ma). Tectonic events in the map area are thus described as a possible chronological sequence and, therefore, generally are associated with the rock groupings defined in the general statement.

Archean Structures

Archean structures occur in supracrustal rocks (Unit 1) and the Sail Lake intrusive suite (predominantly orthogneiss, Unit 2) in the Archean and possible Early Proterozoic rock association (Figure 6), primarily in eastern and northeastern parts of the map area. Structural trends (Figure 13) mainly vary from northeasterly to northwesterly through northerly orientations; locally, however, interference patterns generate considerable departures from the norm.

The most obvious structure in the supracrustal rocks is deformed primary compositional layering (e.g., Plates 3 and 11). However, for the most part this is parallel to the major tectonic-fabric elements, which consist of leucosomes and metamorphic mineral and shape fabrics.

The earliest tectonic structure recognized in the Sail Lake intrusive suite (Unit 2) is a close-spaced, largely concordant location fabric formed by felsic veins in an early tonalite member of subunit 2a (Plate 16). The tonalite occurs only as rafts and inclusions in the main Orma dyke tonalite, which truncates the stromatic layering in the inclusions at the contact. Rarely, similar relationships are seen between leucosome-layered amphibolite inclusions of supracrustal rock (subunit 1a) and the tonalite phases of the Sail Lake intrusive suite, which may be of equivalent or other pre-Orma dyke tonalite timing. The leucocratic veins consist of plagioclase + quartz ± biotite, and were recrystallized during younger events. Their trend is everywhere parallel or subparallel to the local orientation of the main fabrics (see below).

The main phases of the Sail Lake intrusive suite, namely the Orma dyke tonalite and subunits 2b and 2c orthogneiss, all contain variably developed migmatitic structures. These form variably oriented pretectonic felsic-vein sets that now range from random venite and agmatite to concordant stromatic structures. Whereas a diffuse, close-spaced, stromatic layering is an integral part of subunit 2c, concordant leucosome (e.g., Plate 57) is more inhomogeneously developed in the other subunits. It is regarded as having developed from a combination of rotation of pre-existing, more randomly oriented veins during extreme deformation, and of emplacement or in situ development in the XY plane of the finite strain ellipsoid during deformation at high grade. Rarely, the main mineral foliation in the orthogneisses exhibits a subconcordant, crosscutting relationship to the stromatic layering, and in places is axial planar to very tight or isoclinal folds of this same layering. Locally, therefore, the leucosome layering predates the main mineral foliation (although it might still be considered to be in a progressive deformational relationship to the relatively later foliation development).

Some of the Archean supracrustal rocks (Unit 1) also contain stromatic leucosomes. It is a major component of pelitic paragneiss (subunit 1f) and occurs locally in amphibolite (subunit 1a) and thinly bedded metasedimentary rocks (subunit 1d). In parts of subunit 1e, leucosomes have coalesced into thick sheets of diatexite containing minor screens of paragneiss paleosome. Throughout the supracrustal rocks, the stromatic leucosomes are parallel to both the initial compositional layering and the main mineral fabric; they may relate to earlier gneissosity generations than those noted above, or to emplacement of the main orthogneiss protoliths, or, may be synchronous with the gneissosity or the main foliation in the orthogneisses.

Most leucosomes exhibit syntectonic fabrics or posttectonic recrystallization; however, undeformed augen are present containing relicts of the original(?) leucosome mineralogy. The relict composition of the stromatic leucosome within Unit 1 is controlled by the host rock type. Leucosomes are quartzofeldspathic, in which plagioclase dominates microcline and the ferromagnesian mineral species vary. Biotite is ubiquitous and is generally brown to olive. Hornblende is common in leucosomes within amphibolite (subunit 1a) and, in the north, is accompanied by pyroxene. The diatexite (subunit 1e) contains several unusual compositions, including a much greater abundance of K-feldspar. Throughout the Sail Lake intrusive suite (Unit 2), relict compositions in the leucosome location fabric consist of biotite ± hornblende granodiorite and tonalite.

The main Archean tectonic structure is an almost completely penetrative mineral fabric and parallel mineral-aggregate shape fabric (Plate 57) occurring throughout the

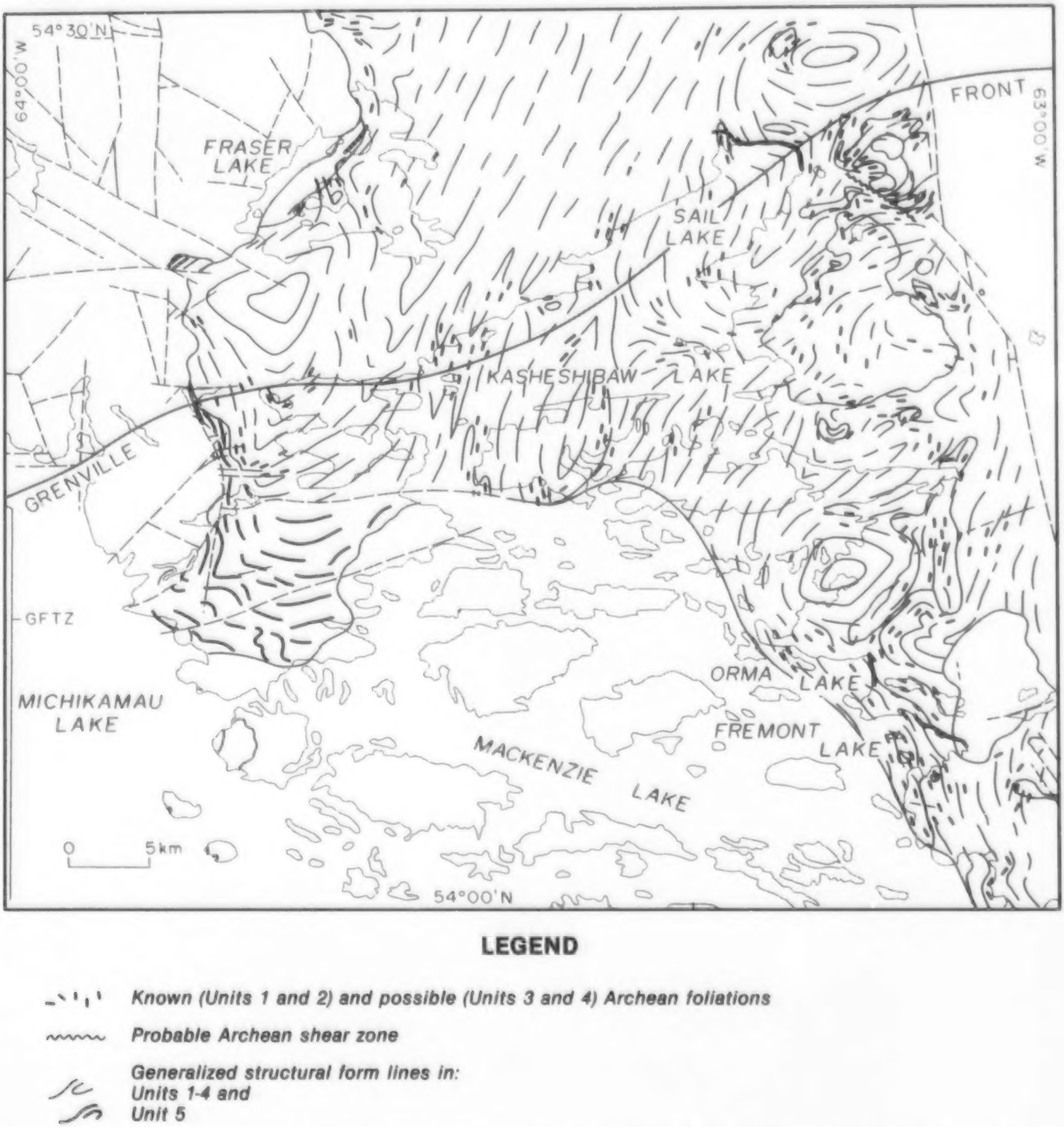

54°30'N
64°00'W
FRASER LAKE
SAIL LAKE
FRONT
63°00'W
KASHESHIBAW LAKE
GRENVILLE
GFTZ
MICHIKAMAU LAKE
ORMA LAKE
FREMONT LAKE
MACKENZIE LAKE
0 5km
54°00'N
LEGEND
Known (Units 1 and 2) and possible (Units 3 and 4) Archean foliations
Probable Archean shear zone
Generalized structural form lines in:
Units 1-4 and
Unit 5

Figure 13. *Archean foliations and Archean and/or younger interference patterns. Note the general conformity between structures in the western part of the Sail Lake intrusive suite orthogneiss (Unit 2) and the Petscapiskau Group supracrustal rocks (Unit 5), and the zone of tightened and isoclinal structures in west-central Kasheshibaw Lake (which is characterized by mylonitic foliations). For unit distributions see Figure 6 or Map 93-19.*

supracrustal rocks (Unit 1) and the orthogneiss suite (Unit 2). Relicts of coarse-grained earlier crystallization, for example, plagioclase in the cumulate metagabbros (subunit 1b, Plate 4) and Orma dyke tonalite (subunit 2a), plagioclase or K-feldspar in subunit 2b (e.g., Plates 19 and 20), rare olivine and pyroxene in ultramafic rock (subunit 1c), and augen of undeformed rock, are sparsely scattered throughout the two units, but are generally elongated in the same direction as the main fabrics that anastomose around them (e.g., Plate 19). This orientation is further enhanced by inclusions, rafts and screens of paragneiss or earlier Unit 2 phases in the orthogneiss (Plates 13 and 14) and by the parallel to

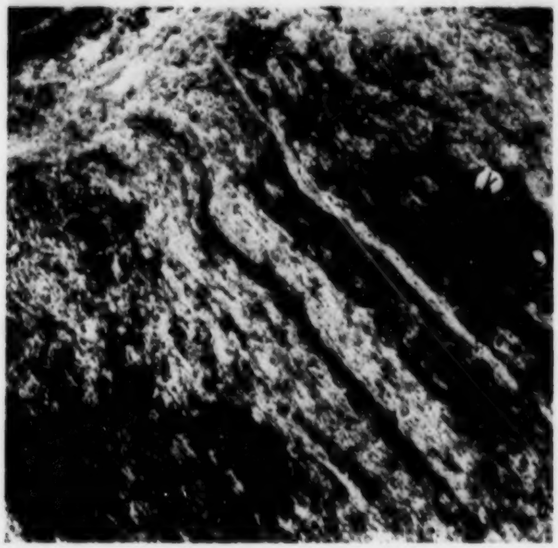


Plate 57. *Orma dyke tonalite (subunit 2a) containing stromatic leucosomes and strong rodding. Photo GN80-CS21-3, locality G458a, NTS 13L/3E, GR 8925.9715. Length of clinometer is 10 cm.*

subparallel stromatic leucosomes (Plate 57). As noted above, the stromatic leucosome is in part a pre-existing feature and is in part developed during the main deformation; quartzofeldspathic veins that are axial or limb-parallel to folds generated during the main deformation, are examples of the latter.

Throughout most of the Archean supracrustal rocks and the Sail Lake intrusive suite, the main structure has a measurable planar component. However, within the paleosome and less commonly within the leucosome, the mineral and shape fabrics define a moderate to strong linear fabric and most rocks are LS tectonites (Plate 57). The lineation is particularly well shown by tremolite in slightly calcareous metasedimentary rocks of subunit 1d, by quartzofeldspathic aggregates and rodding (Plate 18) and mullion-like crenulation of felsic veins (locally) in many phases of subunit 2a, and by plagioclase and hornblende in intergranular-textured metagabbro (subunit 1b) and porphyritic tuffaceous rocks (subunit 1d) that preserve relict primary textures at right angles to the lineation. Tight to isoclinal folds synchronous with the main deformation have fold hinges approaching parallelism with the rodding, except in the younger vein sets and granitic dykes.

Variations in intensity of the main structure are present throughout the map area in terms of both linear and planar components. Apart from the augen of less deformed or undeformed rock, these include shear zones and areas of more intense deformation that are characterized by finer grain sizes (Plate 58) and, commonly, the development of porphyroclastic textures. Porphyroclasts consist of plagioclase, K-feldspar and less commonly hornblende or quartzofeldspathic aggregates.

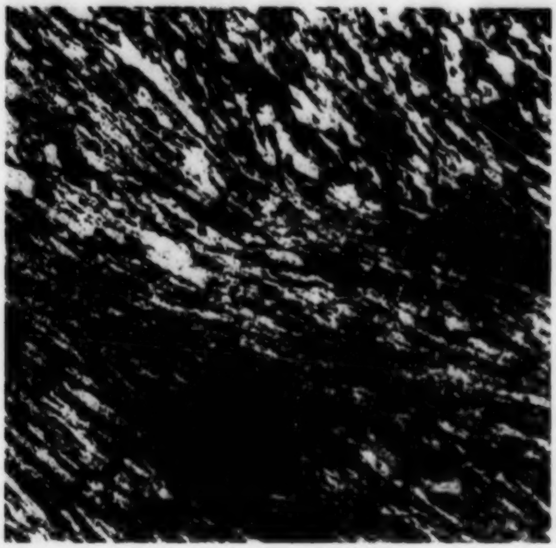


Plate 58. *Foliated metagabbro (subunit 1b) containing shear zone heterogeneities. Photo GN81-CS24-35, locality G531, NTS 13L/3W, GR 8350.9895. Diameter of coin is 1.85 cm.*

These zones are more common and wider in the northeast of the map area; they also increase from east to west toward the west-centre of Kasheshibaw Lake into a zone of northerly trending blastomylonitic rocks. However, in the latter case, it is not clear whether or not the mylonite zones are a more intense development of the main structure or a superimposed episode of deformation, as chevron folds of the main foliation also increase from east to west toward the centre of Kasheshibaw Lake.

Temporal variations in the intensity of the main foliation also have been recognized. At the spillway beneath the Orma dyke, a polyphase intrusive sequence is present in subunit 2a (Table 2). The Orma dyke tonalite is intruded by two formerly medium-grained granodiorite phases (grey- and white-weathering) and a coarser grained cream-weathering granodiorite. The later granodiorite contains quartzofeldspathic aggregates indicating a similar original grain size to the Orma dyke tonalite; however, the felsic aggregates in the Orma dyke tonalite and the intervening granodiorite (Plate 18) display a much stronger lineation than those in the adjacent younger granodiorite. In Kasheshibaw Lake, foliated granite (subunit 2e) contains inclusions of more strongly porphyroclastic rock, which may belong to the same subunit (2e) or to granodiorite gneiss (subunit 2b). Similar examples of zonal intensity variations or tectonic inclusions containing a similar type, and in places orientation, of foliation are common in granodioritic (subunit 2b) and tonalitic (subunit 2a) orthogneiss; these features are easily explained in terms of progressive deformation. In addition, examples are common of granite dykes (e.g., subunit 2g) and felsic veins cutting across a strong fabric in their host and themselves containing a less well developed fabric of the same orientation.

Mineral assemblages associated with the main foliation are dependent on the rock type and, to a lesser degree, the geographic location. In the northeast of the map area, amphibolites (subunits la and lb) contain the assemblage plagioclase–hornblende–opaque mineral ± clinopyroxene, orthopyroxene, biotite, titanite, rare epidote and apatite, whereas in the southeast of the map area they contain plagioclase–hornblende–opaque mineral ± biotite, epidote and titanite assemblages. Ultramafic rocks (subunit lc) become mafic amphibolite in shear zones. Subunit ld comprises many differing assemblages: basic tuffs consist of plagioclase–hornblende–epidote–opaque mineral ± quartz; volcaniclastic rocks in the northeast of the map area are composed of quartz–plagioclase–hornblende (greater than, equal to, or less than) biotite–opaque mineral, and quartz–plagioclase–hornblende–biotite–tremolite–opaque mineral, in which the tremolite occurs as overgrowths on lineated hornblende; pelitic rocks consist of quartz–feldspar–green biotite–garnet–opaque mineral (southern areas only); psammitic to semipelitic rocks are made up of quartz ± microcline and/or plagioclase ± hornblende and/or biotite + epidote ± titanite, zircon and apatite; calcareous quartzite consists of quartz–tremolite–minor feldspar and opaque mineral; and calcareous psammite in the southeast of the map area is composed of feldspar–quartz–hornblende–tremolite–opaque mineral ± biotite in which the tremolite has overgrowths of actinolitic amphibole. Subunit le contains paragneiss and diatexite assemblages that consist of differing proportions of quartz–plagioclase (or two-feldspar)–brown biotite–opaque mineral–zircon and monazite. Pelitic paragneiss (subunit lf) comprises cordierite(?)–sillimanite–biotite–quartz–feldspar–opaque mineral. Quartzite (subunit lg) consists of quartz–muscovite. In the Sail Lake intrusive suite (Unit 2) the essential foliation-forming mineral assemblage is plagioclase and/or microcline–quartz–biotite–an opaque mineral–titanite–apatite–zircon ± hornblende ± epidote ± muscovite.

Structures associated with the main foliation include the enclave elongations, rodding of tectonic inclusions, mullion-like crenulations on the surfaces of felsic veins and on quartzite bedding planes, and the shear zones noted above, together with boudinage of competent layers and rare folding of pre-existing compositional layering and leucosomes. Folds are very tight to isoclinal and the layering is very attenuated and/or boudinaged on the limbs; they occur mostly at outcrop scale. Pre- to syntectonic felsic and granitic veins subparallel to the main fabric are commonly boudinaged or necked (Plate 15). Those at greater angles to the foliation are gently warped to tightly folded, commonly have scalloped or pinched margins, and exhibit considerable thickness variations. Internal fabrics in the veins are very variable in development and controlled mostly by grain size and timing of emplacement during the main-foliation episode. Externally, close to the veins, the foliation ranges from undeflected to complexly distorted around the fold hinges and mullions or into the pinches.

Fractures in the K-feldspar megacrysts in monzogranite (subunit 2e) are consistent with shear and extension during main-foliation development. The two sets of fractures may be coeval or, because of the lower grade mineral assemblage (quartz–epidote–chlorite) associated with the orthogonal pull-aparts, these may be evidence of renewed, later, similar-orientation, brittle deformation. Alternatively, they may be further evidence of temporal longevity of the main strain regime and ongoing development of the main foliation from migmatite grade down into the greenschist facies.

Metamorphic recrystallization continued after deformation ceased and static recrystallization textures are common. Quartzofeldspathic aggregates and veins are commonly affected and coarse-grained ferromagnesian crystals are replaced by isotropically textured aggregates in some areas. In the north of the map area, static recrystallization seems more common, particularly in the diatexite (subunit le), which is dominated by isotropic textures, although in this case, the textures might relate to crystallization of material that was largely, or partly, liquid during the deformation.

The metamorphic grade of the posttectonic crystallization is represented by the assemblages plagioclase–hornblende–biotite–magnetite ± titanite ± quartz ± epidote in amphibolites (subunits la and lb) and plagioclase–quartz–K-feldspar–biotite ± magnetite ± garnet ± titanite in the orthogneiss (Sail Lake intrusive suite, Unit 2) throughout most of the area. Locally, in southern areas, posttectonic crystallization in the orthogneiss is accompanied by garnet or magnetite porphyroblast growth with felsic haloes (? a biotite oxidation reaction; Victor Owen, personal communication, September 1992), and that in the amphibolites (subunits la and lb) and felsic volcanic rocks (subunit ld) by hornblende and, in places, epidote; some ultramafic rocks (subunit lc) contain widespread amphibolitization. In contrast, post-foliation felsic veins in mafic dykes (subunit 2f) intruding amphibolite (subunit la) in the quarry southeast of Sail Lake contain the assemblage plagioclase–quartz–clinopyroxene–orthopyroxene–biotite–amphibole–opaque minerals–titanite–zircon, in which the amphibole forms narrow rims on the pyroxenes. Adjacent to the veins, the normal amphibolite assemblage of plagioclase–hypersthene–hornblende contains less hypersthene and also contains minor biotite and clinopyroxene with thin amphibole rims. These mineral assemblages are interpreted to be the result of generation of relatively dry (two pyroxenes + biotite) leucocratic segregations accompanied by a dehydration reaction in the mafic dyke (hornblende → orthopyroxene). The migmatitic material, however, either introduced enough water (and potassium ?) to form biotite and prevent dehydration in the half-centimetre-wide halo adjacent to the vein or acted as a sink for the water driven off during dehydration of the amphibolite, with the same effect. The narrow amphibole coronas on the pyroxenes could be late, water-saturated, residual (cf. deuteric) crystallization in this system or be a later rehydration. The diatexite (subunit le) contains isotropic textures involving hypersthene or sillimanite, brown to red-brown biotite, garnet and graphic intergrowths of microcline and plagioclase, together with coronas of biotite–quartz around hypersthene and opaque mineral–feldspar(?) around biotite. Partial reactions apparently taking place include hypersthene + biotite → garnet, hypersthene → biotite + quartz, and biotite → biotite + felsic symplectite or biotite → opaque mineral + feldspar(?). In pelitic paragneiss (subunit 1f) in Kasheshibaw Lake, fibrolite needles occur in cordierite(?) but most posttectonic crystallization is composed of the assemblage muscovite–green biotite.

These assemblages indicate that posttectonic crystallization in the northeast of the map area was prograde relative to the main foliation formation, and represents a granulite facies metamorphic culmination for that area, whereas posttectonic recrystallization in the southeast of the map area occurred under similar or waning P–T conditions relative to the main foliation. At the west end of the Sail dyke (tremolite overgrowths on hornblende) and in Kasheshibaw Lake (green biotite and muscovite), conditions appear to have been similar to those in the south.

The main Archean foliation is cut by small, outcrop-scale shear zones. These are common in a few areas, have centimetre-scale widths and displacements and commonly contain leucosome veins along the locus of the shear zones. Locally, the shear zones may be coeval with moderate to tight, outcrop-scale minor folds that contain a weak axial-planar fabric; in general, they predate them. The minor folds affect the layering, earlier leucosomes and the main fabric. Finely layered earlier structures, e.g., biotite-rich schlieren, are crenulated by this fold generation, and, locally, new biotite growth occurs in the crenulation axes.

The main fabric is also folded by open to tight folds at both outcrop and map scale (Figure 13). Types 1 and 3, and rare type 2, interference patterns (Ramsay, 1967), also developed at both scales, indicate at least two generations of folds. In the east of the map area, the earlier axial traces in the interference patterns are subparallel to the dominant, more or less northerly trending, structural trends, whereas the later traces are approximately east-west. Passing westward across Kasheshibaw Lake, the later traces become subparallel to the earlier ones as the zone of mylonites in the west-centre of the lake is approached. It is not known whether the reorientation is due to an intensification of Archean structure that includes the development of the mylonites, or whether it, with or without the zone of mylonites, is a younger superimposed effect, possibly correlative with the mylonite at the orthogneiss (Unit 2)–Petscapiskau Group (Unit 5) contact (see next section). No mineral fabrics are associated with these later fold episodes.

In the southwest corner of the Sail Lake intrusive suite (Unit 2) outcrop area, east and northeast of Contact Lake, the orthogneiss occurs as augen in strongly sheared and mylonitized gneiss and granite. The augen are assumed to contain the usual orthogneiss foliation and migmatization features. (The crosscutting mylonitic fabrics relate to the structural contact between the orthogneiss and the Petscapiskau Group (Unit 5) and are discussed in the next section.)

Greenschist-facies retrograde assemblages that may be late Archean or younger are ubiquitous but generally of minor effect. They consist of saussuritization in all rocks and epidote–chlorite ± biotite and carbonate (subunits 1a, 1b, 1c and 1d), muscovite–chlorite (subunits 1d, 1e and 1f), muscovite–carbonate (subunit 1d), muscovite–chlorite–opaque mineral (subunit 1f), green biotite–chlorite ± rare epidote (subunit 1e), and chlorite–epidote ± green biotite and muscovite (Unit 2).

Archean or Early Proterozoic Structures

Structures assigned to this time range are those that occur in the gabbro–diorite–granite suite (Unit 3), the arkosic metasedimentary rocks (Unit 4), the Petscapiskau Group (Unit 5) and the gneissic tonalite dykes (Unit 6) in the Archean and possible Early Proterozoic rock association (Figure 6) because of the uncertain positions of these units in the deformation chronology. The structures range from penetrative greenschist facies foliation to upper amphibolite facies migmatite development and, potentially, are Archean, Hudsonian or early Labradorian (pre-Trans-Labrador batholith). (After emplacement of the Trans-Labrador batholith, structures in the map area were localized, not pervasive, and did not exceed greenschist grade.) The gabbro–diorite–granite suite occurs in the northeast of the map area, the arkosic metasedimentary rocks in the southeast of the map area, and the Petscapiskau Group and gneissic tonalite dykes in the west of the map area.

Granitoid plutonic rocks of the gabbro–diorite–granite suite (Unit 3) truncate the gneissosity in the Sail Lake intrusive suite orthogneiss (Unit 2). The gabbro (subunit 3a) is mainly undeformed and unmetamorphosed (and may be the protolith of subunit 3b). Subunit 3b is only locally foliated (LS tectonite) but is a thoroughly recrystallized gabbro or diorite and is locally migmatitic. The metamorphic mineral assemblage is plagioclase–clinopyroxene–red-brown biotite–orthopyroxene–opaque minerals ± green hornblende. The migmatitic patches contain the assemblage plagioclase + quartz + hornblende and/or biotite and quartz-rich net-veins and patches ± hornblende, together with grain-size coarsening of plagioclase and hornblende.

A moderate to strong foliation anastomoses through subunit 3c granitic rocks. This foliation is commonly moderately to strongly linear and regionally is more or less parallel to the main Archean fabrics in the adjacent parts of the Archean supracrustal rocks (Unit 1) and the Sail Lake intrusive suite (Unit 2). It is regarded as a late-stage development of the main Archean foliation or as a subsequent-generation fabric formed under a similar strain regime. The foliation contains the mineral assemblage microcline–quartz–plagioclase–biotite–hornblende. Otherwise undeformed augen between the anastomosing bands of foliation contain a few small shear zones bearing the same assemblage; thin, minor shear zones also occur in the gabbro (subunit 3a). Static crystallization occurred within the augen, largely as fine-grained polygonization of feldspar, but also, in one example, it apparently involved the growth of garnet at the expense of biotite. The static crystallization and the small-scale shear zones in the augen were probably synchronous with the anastomosing foliation development, but they could be younger.

Structural trends in Unit 4 are more or less parallel to those in the adjacent gneisses (Units 1 and 2) and granitoid rocks (Unit 9). These structures are of at least two ages. Those that occur in the Naskaupi River outcrops (subunits 4a and 4b) between Marie and Orma lakes relate to a post-Unit 9 mylonite zone and are discussed later.

The arkosic metasedimentary rocks (subunit 4a) are migmatitic. On the basis of structural analyses (this study), the migmatization cannot postdate the emplacement of the Trans-Labrador batholith and is possibly pre-batholith Labradorian, Hudsonian or Archean. From isotopic data (Nunn *et al.*, 1990), it is likely to be either Archean or Labradorian. The leucosome veins consist of a low-colour-index biotite−muscovite granite, which is variably foliated or contains static textures. The foliation is axial planar to moderate to tight asymmetric folds of the veins and of the primary layering in the thinly bedded facies. It forms an indistinct, penetrative, grain-elongation fabric in the arkose at biotite grade. Small pelitic lenses in the outcrops at the east end of Mackenzie Lake contain the same orientation fabric consisting of coarsely crystalline biotite. The schistosity in the mica schist (subunit 4c) is coarse grained and possibly an equivalent feature. Locally, the migmatitic veins in the arkosic metasedimentary rocks (subunit 4a) are folded and a fabric cuts across the outcrop. However, as the fabric is both axial and discordant to the folds in different places, it is likely that both fabric and folds are of more than one generation.

Structures in the Petscapiskau Group (Unit 5) might be Archean, or younger, if the unit correlates with the Archean supracrustal rocks (Unit 1). If, however, the Petscapiskau Group is a cover sequence to the Sail Lake intrusive suite orthogneiss (Unit 2), the structures are likely Hudsonian. Their youngest possible age is early (pre-Trans-Labrador batholith) Labradorian. Structural trends in the group are everywhere parallel to those in the adjacent orthogneiss (Figure 13) although part of the contact between the two is known or assumed to be tectonic in nature. Their orientations are controlled by late regional large-scale folds (see below).

The earliest structures recognized in the Petscapiskau Group are quartz-vein segregations. The segregations are abundant in pelitic subunits (5d,5ef and 5f) but less so in psammitic rocks (subunits 5c and 5e) and amphibolite (subunits 5a and 5b). The veins are very variable in thickness and commonly are folded or boudinaged. Folds are tight to isoclinal and for the most part the veins parallel both the primary compositional layering and the subsequent foliation; the latter is axial planar to the folds.

All subunits in the Petscapiskau Group contain evidence of a major deformation. The deformation is represented by a penetrative bedding-parallel foliation that is enhanced in most sedimentary units by the quartz-vein segregations. Both the quartz veins and the primary compositional layering in thinly bedded parts of the sequence are tightly to isoclinally folded, and the penetrative foliation is axial planar to these folds. The foliation occurs as a penetrative phyllosilicate fabric in the pelitic rocks, as a grain elongation mineral fabric in all rocks, particularly psammite, as clast shape fabrics in conglomerate and hyaloclastite, as flattened pillows, and as shape aggregates wherever minerals have been recrystallized to a finer grain size.

In central and eastern parts of the lobe, farthest from the contact-metamorphic effects of the Michikamau Intrusion (Unit 10) or the Trans-Labrador batholith (Unit 9), the main foliation is defined in the conglomerate matrix and in the pelitic rocks by the regional assemblages green biotite−opaque mineral ± epidote, muscovite and chlorite; brown biotite−opaque mineral−tourmaline−chlorite(?); and chlorite ± opaque minerals and epidote. The strongly flattened, foliated, acid-volcanic clasts in the conglomerate are sericitic. The more competent rhyolitic-porphyry clasts and much of their arenite matrix contain a pressure-solution cleavage. Closer to the two intrusions, the main foliation is partially to completely overprinted by static recrystallization or is mimetically preserved during this process as a mineral layering and/or mineral fabric.

Posttectonic minerals occur even in those areas containing a strong regional fabric. These include brown biotite, epidote, hornblende, muscovite and chlorite. The last two are probably retrogressive. It is not known whether or not the others represent post-main-foliation prograde metamorphism under static conditions or contact metamorphic porphyroblasts.

In the eastern part of Contact Lake, the Petscapiskau Group is thrust over Sail Lake intrusive suite migmatitic granitoid rocks (Unit 2). A mylonitic foliation is developed in the underlying granitoid rocks reducing them to a fine-grained, white, sugary rock. The mylonitic foliation postdates initial migmatization of the orthogneiss, but is of uncertain age relative to the main Archean foliation (see discussion of Archean structures). The mylonitization does not seem to affect the overlying Petscapiskau Group metasedimentary rocks. It appears to be parallel to the bedding-parallel foliation in the metasedimentary rocks and also to the mineral and shape fabrics developed in granite (subunit 2e) just north of Contact Lake. The timing of the mylonite relative to structures in the Petscapiskau Group is unknown, but the generation of a major bedding-parallel fabric in the group and the tight to isoclinal folding of the layering and the quartz veins is consistent with major thrusting.

Moderate to tight asymmetric folding of the Petscapiskau Group sequence postdates the main foliation (Plate 36). Locally, the fold hinge zones contain a fracture cleavage or pressure-solution fabric in arenaceous rocks (Plate 36) and a crenulation is common in the pelite. Much less commonly, the pelitic phyllosilicate foliation is affected by two sets of crenulations on the same surface. This is related to later folding. Whether either, or any, of the crenulations is coeval with the regional folding (see below) is unknown.

The Petscapiskau Group structural trends are controlled by regional-scale, moderately tight to open structures having westerly or west-southwesterly trending axial traces (Plates 36 and 59, Figure 13). The most prominent of these is the antiform affecting the sequence in the lobe. Folding of the mylonitic fabric, east of Contact Lake, is consistent with deformation by this generation of folding, although the variable orientations and shallow dips prevalent between Contact Lake and westernmost Kasheshibaw Lake suggest an interference relationship (compare with Plate 59). Furthermore, from Contact Lake northward to Fraser Lake, structures in the Petscapiskau Group are parallel to those in the adjacent orthogneiss and, notwithstanding a general lack of data, structural trends in the gneiss appear to be the result of interference folding (Figure 13).

Plate 59. *Interference fold patterns in quartz vein segregations in massive pelitic paragneiss (subunit 5f); aureole of the Michikamau Intrusion (Unit 10). Photo GN81-CP36-11, locality G690 (The Buttress), NTS 13L/5W, GR 4666.2395. Length of hammer is 34 cm.*

Therefore, despite the likelihood that the regional folding of earlier fabrics in both the Sail Lake intrusive suite (Unit 2) and the Petscapiskau Group (Unit 5) is coeval, the age of the interference structures is still problematic. Interference patterns of similar type occur in the Archean Nain (Collerson and Bridgwater, 1979; Van Kranendonk, 1990) and Superior (Percival, 1987; Percival and Girard, 1988) cratons to both the east and west, respectively, of the Rae Province, but also occur, along with thrusting, mylonites and bedding-parallel fabrics, in supracrustal rocks infolded with the gneisses in the Rae Province itself (e.g., Moorhead and Hynes, 1990; Wares and Goutier, 1990). Interference patterns in the Nain and Superior provinces are Archean structures, those in the Rae Province are Early Proterozoic structures that fold Archean fabrics in the basement gneisses and Hudsonian fabrics in the infolded supracrustal rocks, which are themselves Early Proterozoic. In the map area, these regional folds predate thermal metamorphism induced by the Trans-Labrador-batholith (North Pole Brook Intrusive Suite, Unit 9) and the Michikamau Intrusion (Unit 10).

Unit 6 consists of gneissic tonalite sheets and composite tonalitic dykes, containing country-rock (or restite) screens and schlieren, that intrude the Petscapiskau Group (Unit 5) on Rusty Island in Fraser Lake. Aside from the location fabrics and the screens, all structures are destroyed by contact metamorphism due to emplacement of the Michikamau Intrusion (Unit 10). The relationship of these structures to those in the nearby orthogneiss (Unit 2) and to those in the Petscapiskau Group (Unit 5) is uncertain.

Labradorian Contact Metamorphism

The granitoid rocks of the Trans-Labrador batholith (North Pole Brook Intrusive Suite, Unit 9) have had no known effect on Unit 1 supracrustal rocks, Unit 2 orthogneisses or many of the xenoliths and inclusions that they contain (Unit 7). However, they contact metamorphose the Petscapiskau Group (Unit 5; Figure 14) and the Mackenzie Lake group (Unit 8).

At the eastern end of the lobe of the Petscapiskau Group rocks, the greywacke (subunit 5d) is spotted by cordierite(?) in the east of the outcrop, through amphibole(?) or staurolite(?), to chloritoid in the west of the outcrop. Andalusite occurs in quartz veins in the cordierite(?) and amphibole(?)/staurolite(?)zones. In the chloritoid zone, chloritoid occurs as random euhedral plates and sheaths, muscovite and tourmaline occur as ragged to subhedral poikiloblasts, and rare garnet is also present. These minerals are surrounded by a fine isotropic mesh of chlorite + muscovite ± quartz. Feldspar appears to have been completely pseudomorphed by a sericitic mesh, in particular along the margins of quartz veins. The muscovite and tourmaline overprint an earlier porphyroblastic phase consisting of an unknown dark-brown mineral that has a very strong body colour and contains numerous parallel lamellae of a white-mica phase (oxidized biotite(?), Bruce Ryan, personal communication, October, 1991). The three zones occur across an outcrop width of about 400 m. This represents a narrow aureole and the Trans-Labrador batholith contact is inferred to lie just east of this outcrop area (although the granitoid rocks are unexposed).

In the centre of the lobe, pelite (subunit 5f and that intercalated with the fine-grained facies of subunit 5c) contains blue-green hornblende, brown biotite and epidote porphyroblasts that overprint a greenschist-facies foliation. Posttectonic, peak-metamorphic crystallization related to the regional foliation is regarded as a less likely explanation for these porphyroblasts than thermal overprinting. However, the distances involved, to the Michikamau Intrusion (Unit 10) to the west and the inferred contact of the Trans-Labrador batholith (Unit 9) to the east or south, seem too great given the known effects of these two intrusions (see Appendix 2, column 6). An underlying stock or a cupola in the batholith represent plausible heat sources.

Northeast of the east end of Mackenzie Lake, the continental clastic roof pendant (Mackenzie Lake group, subdivision $8b^2$) is contact metamorphosed at hornblende–hornfels facies. Different layers have widely differing plagioclase : microcline : quartz ratios. The index

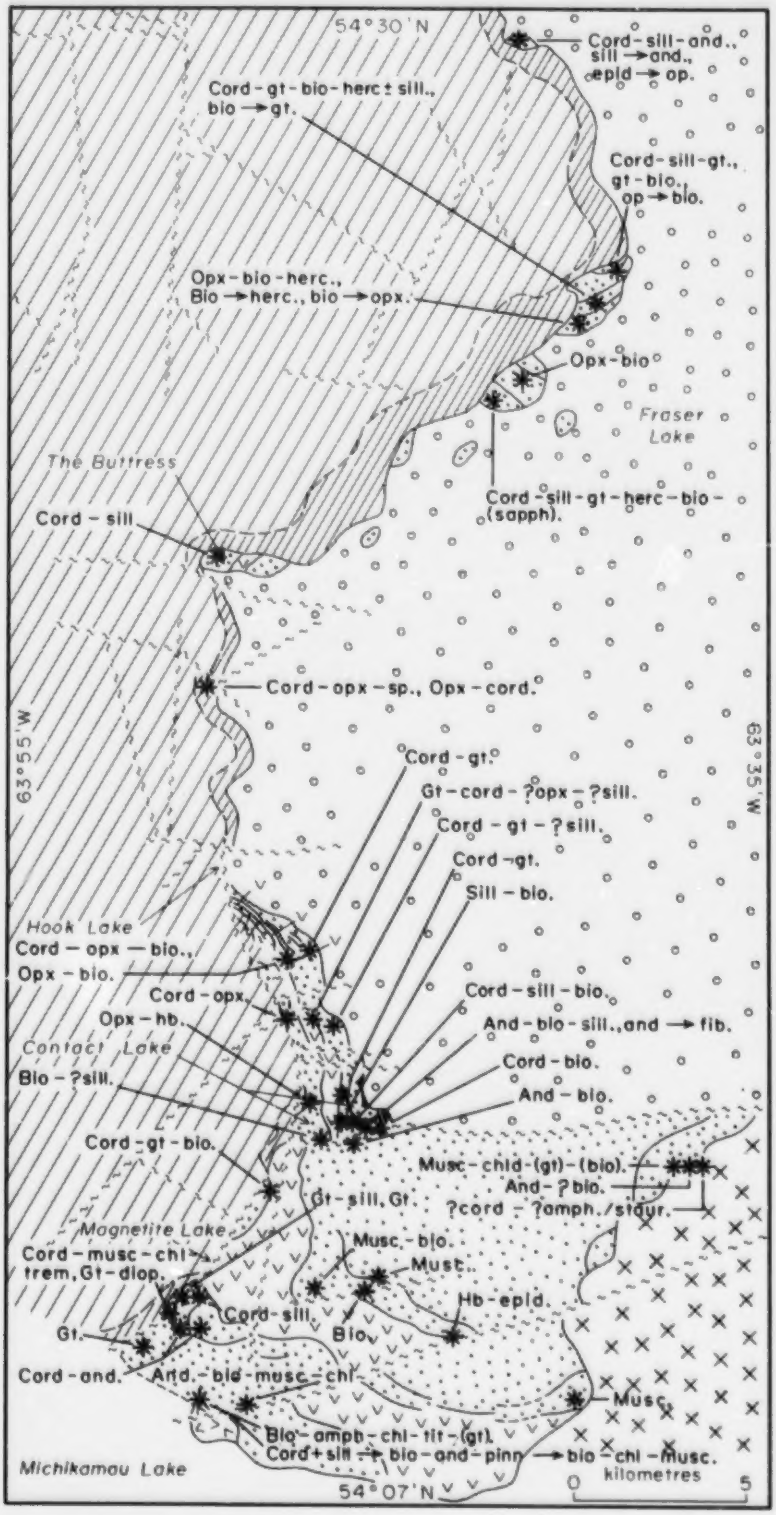

54°30'N
Cord-sill-and., sill → and., epid → op.
Cord-gt-bio-herc ± sill., bio → gt.
Cord-sill-gt., gt-bio., op → bio.
Opx-bio-herc., Bio → herc., bio → opx.
Opx-bio
Fraser Lake
The Buttress
Cord-sill-gt-herc-bio-(sapph).
Cord-sill
Cord-opx-sp., Opx-cord.
63°55'W
63°35'W
Cord-gt.
Gt-cord-?opx-?sill.
Cord-gt-?sill.
Cord-gt.
Sill-bio.
Hook Lake
Cord-opx-bio., Opx-bio.
Cord-opx.
Opx-hb.
Contact Lake
Bio-?sill.
Cord-sill-bio.
And-bio-sill., and → fib.
Cord-bio.
And-bio.
Cord-gt-bio.
Musc-chld-(gt)-(bio).
And-?bio.
?cord-?amph./staur.
Gt-sill, Gt.
Magnetite Lake
Cord-musc-chl-trem, Gt-diop.
Musc.-bio.
Must.
Cord-sill.
Hb-epid.
Gt.
Bio
Cord-and.
And.-bio-musc-chl
Musc.
Bio-amph-chl-tit-(gt).
Cord + sill → bio-and-pinn → bio-chl-musc.
Michikamau Lake
54°07'N
0
5
kilometres

Figure 14a.

LEGEND

Unit

10 **Michikamau Intrusion:**
▤ *layered series*
▨ *marginal zone*

9 **North Pole Brook Intrusive Suite:**
× × *granitoid rocks*

8 **Mackenzie Lake Group:**
<ʳ> *andesite*

5 **Petscapiskau Group:**
v v v *metabasic rocks*
⁖ *metasediment and paragneiss*

2 **Sail Lake Intrusive Suite:**
○ *orthogneiss*

Figure 14. *Selected probable index-mineral assemblages generated in the aureoles of the North Pole Brook Intrusive Suite and the Michikamau Intrusion.* **a:** *metasedimentary rocks and paragneiss (Petscapiskau Group); b: metabasic rocks (Petscapiskau Group) and andesite (Mackenzie Lake group); and c: granitoid orthogneiss (Sail Lake intrusive suite). Partial reactions indicated by a thin section study are given in parentheses. For details of the geology and the subunits in the Petscapiskau Group see Map 93-19. Staur. = staurolite, fib. = fibrolitic sillimanite; other abbreviations as in Appendix 2.*

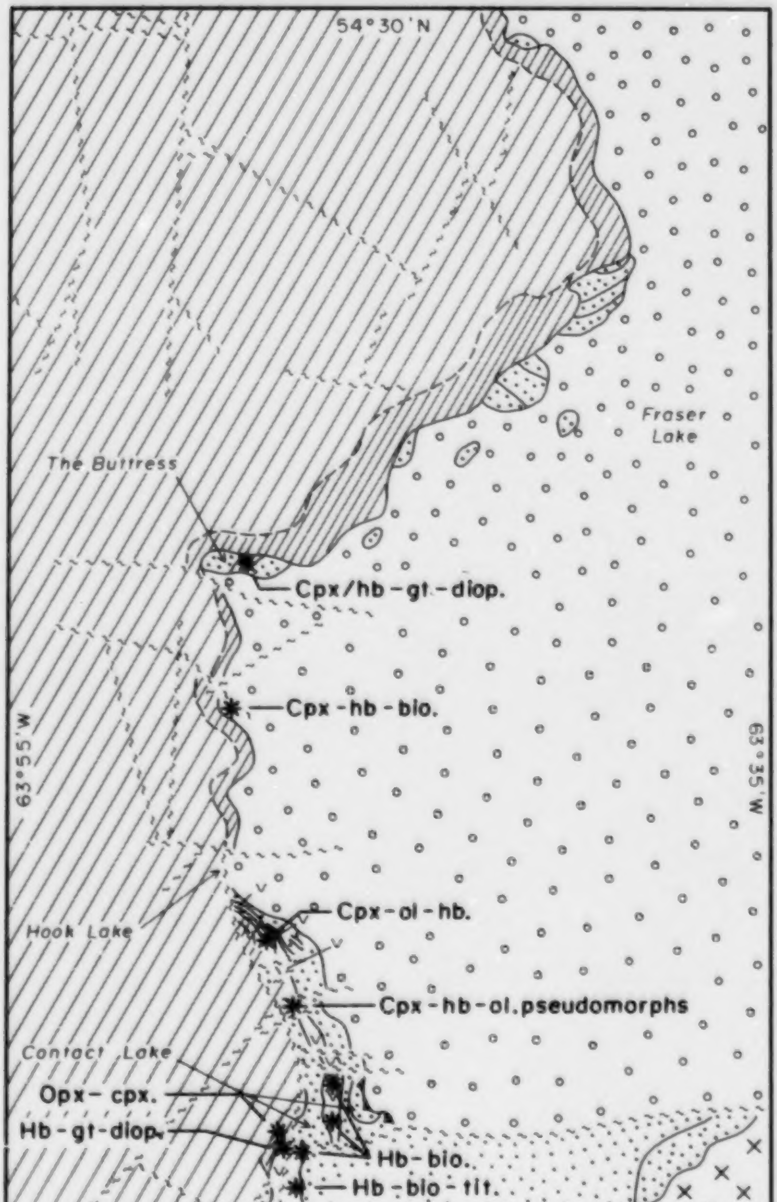


Figure 14b.

assemblages are included within green hornblende–olive-green or brown biotite–diopside–opaque minerals–titanite + minor epidote, muscovite, chlorite and zircon. Ferromagnesian porphyroblasts commonly have quartz–feldspar haloes, and textural evidence for various reactions is present between the ferromagnesian minerals. Early mineral growth included the development of porphyroblastic biotite, plagioclase and clinopyroxene. Green hornblende grew during both the breakdown of biotite (biotite → hornblende + an opaque phase) and the hydration of clinopyroxene (clinopyroxene ± microcline → hornblende), and commonly is poikiloblastic. Other, locally poikiloblastic, contact-metamorphic phases include plagioclase, epidote, opaque minerals and clots of biotite + an opaque mineral. Evidence of partial retrograde reactions is abundant; these reactions include clinopyroxene → hornblende, hornblende → titanite and/or epidote, plagioclase → saussurite, microcline → white mica, and the development of pseudomorphs and clots of epidote ± titanite, an opaque mineral + hornblende + quartz + biotite, and an opaque mineral + chlorite. The retrograde assemblages are of uncertain age, and possibly much younger than the thermal aureole phases.

Northwest of the west end of Mackenzie Lake, clastic metasedimentary rocks (Mackenzie Lake group, subdivision $8b^1$) are similarly affected. Porphyroblastic, commonly poikiloblastic, minerals are plagioclase, biotite, opaque minerals, clinopyroxene and rare hornblende. Spotting also occurs as poikiloblastic clots of K-feldspar + clinopyroxene + an opaque mineral, and biotite + an opaque mineral. The former assemblage formed by the prograde dehydration of biotite. Subsequent waning temperatures are indicated by the localized occurrence of biotite rims on opaque porphyroblasts, hornblende rims on clinopyroxene porphyroblasts, and hornblende and rare titanite in the feldspar–clinopyroxene–opaque mineral clots. These reactions indicate a metamorphic peak in the hornblende-hornfels facies.

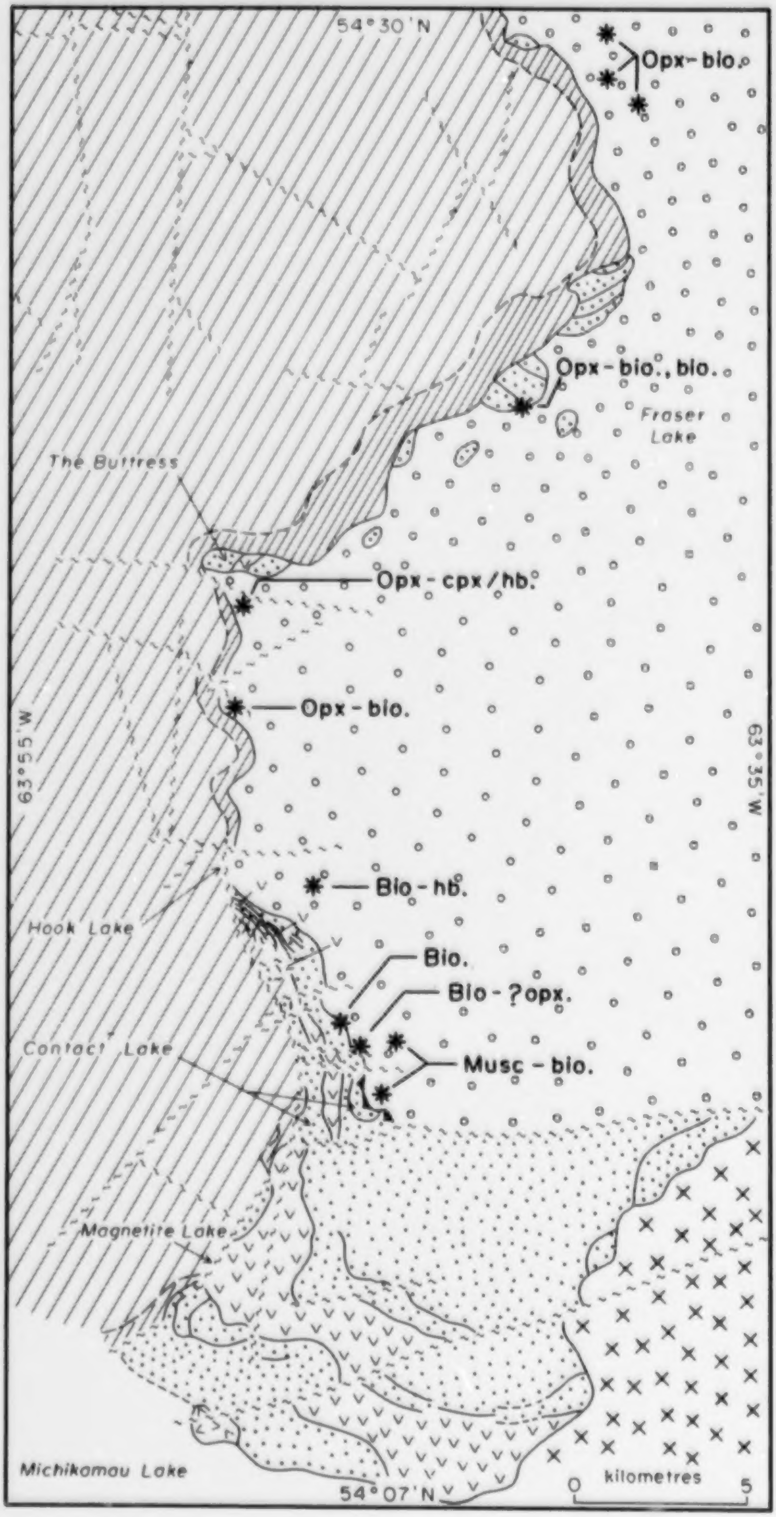


Figure 14c.

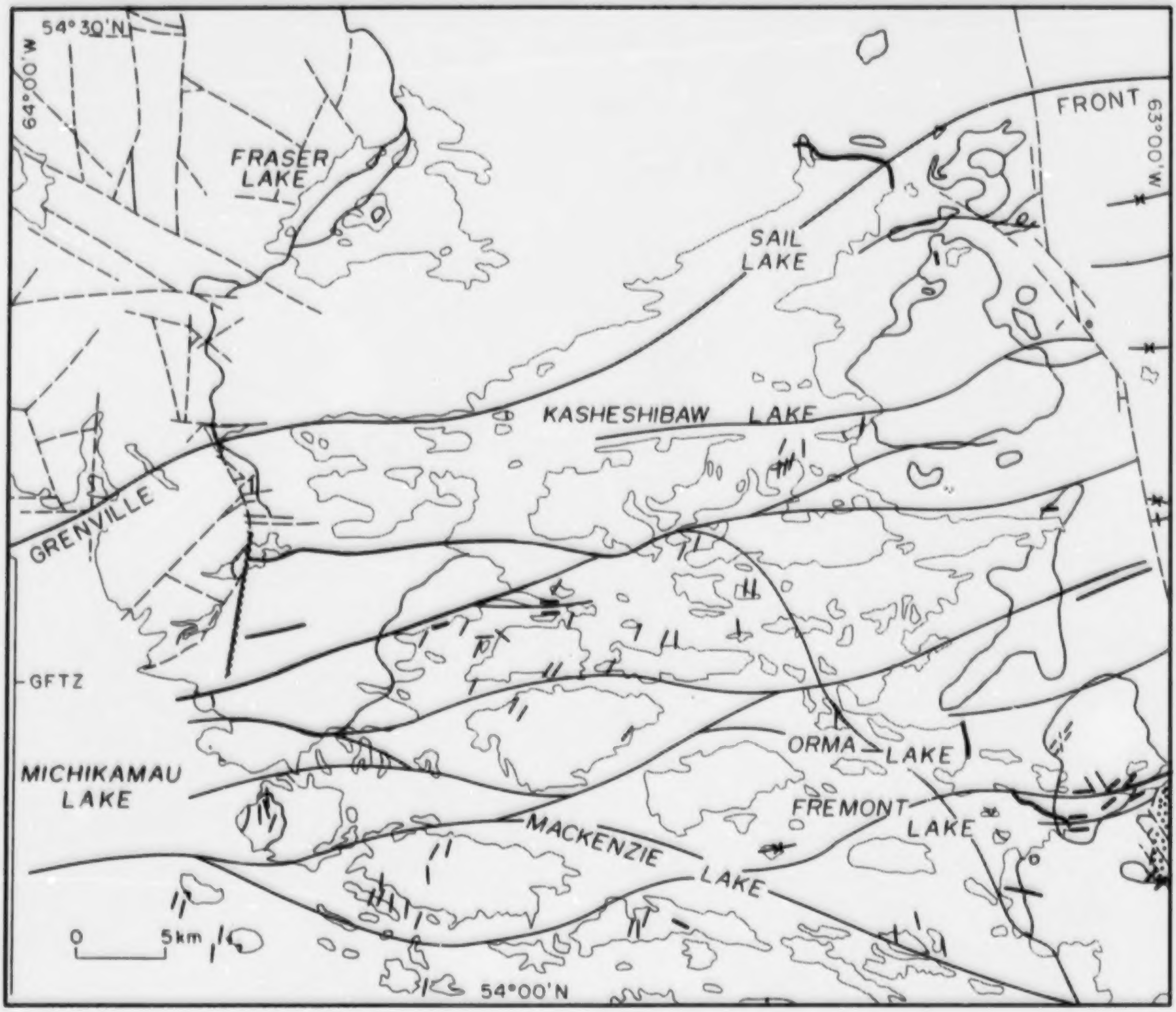
West of Mackenzie Lake, acidic volcanic rocks (Mackenzie Lake group, subunit $8a^4$) contain evidence of hornblende-hornfels-facies and albite–epidote-hornfels-facies metamorphism. Porphyroblasts of biotite, epidote, titanite and apatite occur in a matrix of epidote, green biotite, hornblende, opaque minerals, titanite and felsic minerals. Quartz-rich ocellae are recrystallized to clots of quartz–amphibole–green biotite ± epidote, plagioclase, titanite, an opaque mineral, allanite, muscovite and zircon.

Labradorian Structures

Labradorian (or younger) structures occur in the Mackenzie Lake group (Unit 8) and the North Pole Brook Intrusive Suite (Unit 9) of the late Early Proterozoic rock association (Figure 6). In general, they consist of a subvertical to steeply eastward-dipping, north-northeasterly trending foliation (Figure 15). The fabric is made up mostly of planar elements but locally there is a linear component. Variations in strike occur from north-northwesterly to east-northeasterly, mainly due to rotation near younger (Grenvillian) shear zones, and very rarely the fabric is more tightly folded (e.g., in Connecting Lake). Commonly, it is not known whether the approximately northeasterly trends are due to rotation of a Labradorian structure in a Grenville shear zone or represent a fabric relating to the younger event.

Most fabrics in the Mackenzie Lake group volcanic rocks (subunit 8a) are primary-flow foliations and the clastic metasedimentary rocks (Mackenzie Lake group, subunit 8b) are undeformed. However, in parts of the dacite (subdivision $8a^4$), a greenschist-facies foliation anastomoses round feldspar phenocrysts and quartz ocellae. The metamorphic groundmass assemblage consists of quartz–feldspar–biotite–epidote–opaque minerals, or quartz–biotite–feldspar–epidote.

The localized distribution of Labradorian structures in the Mackenzie Lake group (Unit 8) may be due, in part, to protection from deformation by Labradorian thermal metamorphism (see previous section).


54°30'N
64°00'W
63°00'W
FRASER LAKE
SAIL LAKE
FRONT
KASHESHIBAW LAKE
GRENVILLE
GFTZ
MICHIKAMAU LAKE
ORMA LAKE
FREMONT LAKE
MACKENZIE LAKE
0
5km
54°00'N

LEGEND

LABRADORIAN STRUCTURES

/ \ *Foliation*

GRENVILLIAN STRUCTURES

∴ *Area of relatively pervasive foliation*

/ | \ *Probable Grenvillian foliations*

— *Possible Grenvillian faults and shear zones*

— *Speculative Grenvillian faults and shear zones*

〰 *Possible Elsonian structure reactivated during Grenvillian events*

Grenvillian folds (syncline, anticline)

Figure 15. *Labradorian and Grenvillian structures in the Grenville Front Tectonic Zone. The pattern of speculative Grenvillian faults and shear zones is based mainly on the area to the south where Grenvillian foliations are more common (Nunn, 1982 and unpublished data).*

In the Trans-Labrador batholith (North Pole Brook Intrusive Suite, Unit 9), the foliation is commonly very weak and represented only by a plagioclase ± K-feldspar orientation. The groundmass in these rocks appears to consist of a normal anhedral granitic texture. Where xenoliths are present, they are usually oval and flattened, and oriented parallel to other elements of the fabric. In places, the foliation is stronger: biotite and quartz display a mineral fabric and plagioclase–biotite–quartz groundmass patches are elongated. The granite stock near the centre-south of the map area (subunit 9g) has a well-developed groundmass mineral fabric and a strong planar orientation of primary, tabular, K-feldspar phenocrysts.

Elsonian Contact Metamorphism

An extensive metamorphic aureole occurs around the Michikamau Intrusion (Unit 10). The aureole occurs in the Sail Lake intrusive suite (Unit 2) and the Petscapiskau Group (Unit 5) of the Archean and possible Early Proterozoic rock association (Figure 6) and in the Mackenzie Lake group volcanic rocks (subunit 8a) of the late Early Proterozoic rock association (Figure 6) where the latter is near enough to the intrusion. In the Petscapiskau Group (Unit 5), it is at least three, and possibly five or more, kilometres wide. The orthogneiss (Sail Lake intrusive suite, Unit 2) is affected up to at least 1.6 km from the contact east of Hook Lake, and andesitic rocks (subdivision $8a^2$ of the Mackenzie Lake group) south of the intrusion contain patches of coarse crystallization interpreted to be the effects of thermal metamorphism at 3.0 to 3.5 km from the contact.

The Michikamau Intrusion is regarded by Emslie (1970) as funnel shaped with a gently to moderately westward-dipping contact (*op. cit.*). Consequently, the width of the aureole determined on the ground is likely to be considerably greater than that orthogonal to the contact. However, this is in part offset by the opposite effect of the faulting in the area, although neither effect can be quantified. Much of the intrusion contact is faulted and the marginal zone (subunit 10a) commonly is cut out by east-side-up faulting, thus reducing the width of the aureole. Similarly, the major Grenvillian faults cutting the aureole are south-side-up reverse faults, which also reduce the width of the aureole. Both effects also apply to the mineral isograds.

Selected contact metamorphic mineral assemblages are given in Figure 14 and approximate mineral isograds are summarized in Table 3. Both are based on the assemblages given in more detail in Appendix 2. All data, however, are generalized due to lack of exposure outside of the high-grade parts of the aureole, limited thin-section control, and problems of identification of some minerals (see notes to Appendix 2).

* Olivine and brown hornblende are excluded from the metabasic rock column in Table 3 because it is uncertain whether or not they occur in rocks belonging to the marginal zone of the intrusion (subdivision $10a^1$ sills rather than subunit 5a or 5b layers). They occur with augite and plagioclase in a granoblastic–polygonal texture up to 0.3 km from the contact.

In the metabasic rocks, orthopyroxene occurs in leucosomes in amphibolite at a greater distance from the intrusion than the amphibolite to pyroxene-granulite transition (i.e., at a lower temperature). This is attributed to a greater partial pressure of water in the amphibolite, stabilizing hornblende to a greater temperature or lower pressure (Wells, 1979). It is likely that the same process is responsible for the successive appearance of orthopyroxene in orthogneiss before pelitic rocks, and in pelite before metabasic rocks. This relationship is typical of dehydration processes during prograde metamorphism, and also has been documented in granitoid gneiss and metabasic rock within the aureole of the Rogaland anorthosites in southwestern Norway (Tobi *et al.*, 1985; Jansen *et al.*, 1985). The orthopyroxene veins that occur in the pelitic rocks close to the intrusion contact between Contact Lake and The Buttress were not melts but may be wide restite seams left behind during partial melting. A similar process occurs in granitoid rocks in the presence of CO_2-rich fluids, according to the partial reaction

Bio. + Qz. + Ksp. + V. → Hyp. + L (Wendlandt, 1981).

Locally, in these same rocks, orthopyroxene porphyroblasts having felsic halos and that are enclosed in cordierite indicate a partial reaction

Cord. → Hyp. + Ksp.

In the metabasic rocks, uncertainty in the positions of the diopside-, garnet- and hornblende-in isograds and of the titanite-out isograd is mainly due to a lack of definitive data. The metabasic rocks are hornblende porphyroblastic over a range of at least 2.0 to 0.4 km from the contact, and hornblende porphyroblasts also grew in feldspar- and diopside-rich segregations between 0.5 and 0.3 km from the contact. Garnet is not common and its occurrence is probably compositionally controlled. Lack of exposure makes the position of the hornblende-in isograd in the orthogneiss uncertain too. In both rock types, hornblende is likely to occur in a fairly wide zone, and hornblende-out to coincide with orthopyroxene-in, for example,

Hb. + Qz. → Cpx. + Opx. + Plag. + V. (Wells, 1979);

with an allowance for metastable overlap. (Such an overlap might in part also be due to the development of orthopyroxene from biotite-consuming reactions rather than the destruction of hornblende.)

In the pelitic rocks, thin-section study has revealed considerable complexity, and the mineral isograds are based on the most prevalent assemblages. However, evidence of disequilibrium and of both prograde and retrograde reactions is abundant.

Andalusite occurs as porphyroblasts in grey, phyllitic pelite laminae in quartzite, 2.9 km from the southern contact of the Michikamau Intrusion. Pelite clasts in conglomerate 2.2 km from the contact contain long, randomly oriented,

Table 3. Approximate mineral isograds in orthogneiss, pelitic rocks and metabasic rocks, relative to the intrusion contact, in the thermal aureole of the Elsonian Michikamau Intrusion

Distance (km) from Contact	Sail Lake intrusive suite	Petscapiskau Group	
	Orthogneiss	Pelitic rocks	Metabasic rocks
		Opx. veins (≤0.1 km)	
0.1			Opx.-in in host metabasic (<0.2 km)
0.2			Opx.-in in leucosome sweats (<0.3 km)
0.3			Aug.-in (? <0.4 km)
0.4			
0.5		Opx.-in (0.5-0.6 km)	Diop.-in (<1.0 km, possibly <0.5 km)
0.6			Gt.-in (<1.0 km, possibly <0.5 km)
0.7			
0.8		Herc.-in (≈0.8 km)	Tit.-out (0.5-1.0 km)
0.9			
1.0	Opx.-in, r-b. bio.-in (≥1.1 km)	R-b. bio.-in (≈1.0 km)	
1.1	Musc.-out (<1.2 km)	Sill.-in (≈1.1 km)	
1.2			
1.3			
1.4	Hb.-out (≤1.5 km, probably <1.1 km)		
1.5			
1.6	Hb.-in (≥1.6 km, probably >2.0 km)		
1.7			
1.8			
1.9		Gt.-in (≤2.0 km)	
2.0		Gn. bio.-out (≈2.1 km)	Hb.-in (>2.0 km)
2.1		Cord.-in (≈2.1 km)	
2.2			
2.3			
2.4			
2.5			
2.6			
2.7			
2.8			
2.9		And.-in (≥2.9 km)	
3.0			

Abbreviations: And.–andalusite, Aug.–augite, Bio.–biotite, Cord.–cordierite, Diop.–diopside, Gt.–garnet, Herc.–hercynite, Hb.–hornblende, Musc.–muscovite, Opx.–hypersthene, Sill.–sillimanite, Tit.–titanite, gn.–green, r-b.–red-brown.

white prisms mapped as sillimanite; however, only andalusite was found in thin section. Because of its habit, the andalusite is assumed to be retrogressively pseudomorphing sillimanite, which, along with pinitized cordierite and relict garnet from the same locality, possibly represents an earlier peak-metamorphic assemblage. Green biotite is replaced by brown biotite in metasedimentary rocks (subunits 5c and 5f) at about 2.1 km east of Magnetite Lake, and the first occurrence of cordierite, together with garnet, is defined at a similar distance from the contact. Andalusite and sillimanite are both present 0.5 to 1.0 km south of Magnetite Lake; therefore, either one of the two is metastable or the rock contains a univariant assemblage.

In contrast to the apparent retrograde relationships exhibited south of the intrusion, pelite in the east of Contact Lake contains prograde relationships. Large andalusite porphyroblasts are corroded by cordierite and K-feldspar and locally replaced by tufts of fibrolite. The cordierite probably grew according to reactions such as

$$\text{And.} + \text{Bio.} + \text{Qz.} \rightarrow \text{Cord.} + \text{Ksp.} + \text{V.}$$

and the fibrolitic sillimanite by polymorphic substitution. (Fibrolite, however, might also form as a metastable replacement of other aluminosilicates (Pitcher, 1965) during retrogression.) Less aluminous compositions possibly also grew garnet or iron oxide. There are at least two generations of cordierite growth in some of these rocks.

In all areas north of Contact Lake, pelite occurs only in high-grade zones of the aureole. Cordierite + biotite + sillimanite assemblages are the most common, although rarely one (or two) of these is absent, whereas garnet, spinel and orthopyroxene are more restricted in distribution and more dependent upon compositional controls. Green spinel ± an opaque mineral commonly occurs in cordierite-bearing aggregates that are surrounded by narrow ferromagnesian-free haloes. Locally, sillimanite is relict in these aggregate cores and epidote grew (instead of hercynite or magnetite) where the aggregates are in contact with plagioclase-rich veins. These relationships are indicative of either a higher grade cordierite-forming reaction than that in Contact Lake, for example,

$$\text{Sill.} + \text{Bio.} + \text{Qz.} \rightarrow \text{Cord.} + \text{Sp.} + \text{Ksp.} + \text{V.}$$

or the development of the product in quartz-free areas (probably depleted by earlier cordierite-forming reactions), for example,

$$\text{Sill.} + \text{Bio.} \pm \text{Gt.} \rightarrow \text{Cord.} + \text{Sp.} + \text{Ksp.} + \text{V.}$$

as noted by Owen (1991) adjacent to the Mistastin granitoid batholith 120 km or more to the north. In the same rocks, hypersthene has grown at the expense of biotite, for example,

$$\text{Bio.} + \text{Qz.} \rightarrow \text{Hyp.} + \text{Ksp.} + \text{V.}$$ (Newton and Hansen, 1983),

or

$$\text{Bio.1} + \text{Qz.} \rightarrow \text{Hyp.} + \text{Bio.2} + \text{Ksp.} + \text{V.}$$ (Tobi *et al.* 1985).

Biotite is usually red-brown where in association with hypersthene; however, there is considerable overlap of brown and red-brown biotite in the pelites, and either the colour is compositionally controlled (? Ti content) within a given range of conditions or brown biotite persists where formation of new biotite is not a part of the recrystallization process. These reactions are prograde.

One very small, pale blue, subhedral grain of sapphirine was found enclosed in quartz(?) or cordierite(?), which in turn is intersertal to laths of brown biotite.

Andalusite close to the intrusion north of Fraser Lake possibly formed during cooling in the aureole. Retrograde reactions are widespread but minor and consist of transformations such as

$$\text{Cord.} + \text{Sill.} \rightarrow \text{Pinn.} + \text{Musc.}\ (+\ \text{Qz.}),$$

$$\text{Hyp.} \rightarrow \text{Amphibole},$$

$$\text{Hyp.} + \text{Ksp.} \rightarrow \text{Bio.} + \text{Qz. symplektite.}$$

Quartzite and psammite (subunit 5e) lack the areal distribution needed to estimate isograd positions in these rock types. Close to the intrusion, calcareous members of the subunit contain diopside, garnet, opaque minerals, tremolite, cordierite and unidentified ferromagnesian minerals. Elsewhere, quartzite contains garnet, except at the locality 2.9 km southeast of the intrusion contact (Figure 14a), and opaque minerals are a ubiquitous but minor component. In psammite, garnet occurs up to at least 1.3 km from the contact, and red-brown biotite occurs, locally, as much as 1.5 km from the contact. Green biotite is present in psammite and quartzite at 2.2 km and in quartzite at 2.9 km. At the former locality (on the shore of Michikamau Lake south of the intrusion), green biotite occurs with amphibole, titanite and tourmaline, and at the latter, it occurs with muscovite. In both localities, interbedded pelitic laminae also contain some of these minerals along with andalusite.

On the shore of a northeastern extension of Contact Lake, near the contact between the Petscapiskau Group (Unit 5) and granitoid orthogneiss to the east (subunit 2b), Emslie (1970) records a 'coarse wollastonite-quartz rock', which may have been formed by 'contact metamorphism of carbonate-rich beds by the granite' (*op. cit.*, page 9). Quartzite (subunit 5e) occurs in this relative position just to the south along the same inlet, and calcareous varieties are known from this subunit (near Magnetite Lake). An alternative paragenesis might be thermal metamorphism by the Michikamau Intrusion, either of these rocks or of the sugary, mylonitic rock that occurs at this contact where it is a thrust.

In the andesite (Mackenzie Lake group, subunit 8a), approximately 3.2 km south of the intrusion, the transition from black hornblende to actinolite to epidote in some of the larger patches of coarse crystallization indicates passage from hornblende-hornfels to albite–epidote-hornfels during the crystallization history of the patches.

Elsonian Faulting

The Michikamau Intrusion (Unit 10) is broken up by many faults (Figure 6a) as demonstrated by rotation of the internal layering and faulting out of marginal units against the country rocks. A few faults cut right through the intrusion, some have trends in common with external faults or lineaments, others probably developed due to different responses to the stress fields in the intrusion as opposed to the country rocks; all of these may be Elsonian or younger. Many, however, appear confined to the intrusion, some of which are thought to relate to post-consolidation brittle tectonics soon after emplacement. Perhaps these faults were the result of continued epeirogenic tectonic adjustments following emplacement and crystallization of the intrusion in an anorogenic setting, an hypothesis also advanced by Emslie (1970). Rarely, faults contain evidence of shearing and exhibit a foliation, e.g., along Narrow Lake.

Grenvillian Structures

Grenvillian structures are most readily identified in the North Pole Brook Intrusive Suite (Unit 9) and the Seal Lake Group (subunit 11a) of, respectively, the late Early Proterozoic and Middle Proterozoic rock associations (Figure 6). They have had little effect or are confined to faulting, as in rocks of the Archean and possible Early Proterozoic association (Units 1 to 5, Figure 6) and the Middle Proterozoic Michikamau Intrusion (Unit 10, Figure 6), in many rocks of the area. Throughout the area, the structures vary in trend from approximately easterly to northeasterly (Figure 15). They consist of an anastomosing set of moderately to steeply south-dipping shear zones in the North Pole Brook Intrusive Suite granitoid rocks (Unit 9), faults of similar trend but with moderate to subvertical dips to the north and south in the granitoid rocks (Unit 9) and the Seal Lake Group (subunit 11a), folding in the Seal Lake Group, and a non-penetrative foliation in Seal Lake Group basalt (subdivision $11a^2$).

Shear zones in the North Pole Brook Intrusive Suite contain a shape and mineral fabric of granitoid components that rarely has a weak, steeply pitching lineation. The shear-zone foliation is defined by the greenschist-facies assemblage feldspar–quartz–chlorite–epidote–opaque minerals.

The foliation in the basalt (subdivision $11a^2$, south of Marie Lake) is defined by an oriented assemblage of chlorite–epidote–opaque minerals–amorphous brown material, and, although relicts of the original mineralogy are common, much of the intervening rock is statically altered to a similar assemblage. This facies is further emphasized by chlorite, epidote, carbonate and chalcedony vesicle alteration, and epidote–chlorite ± muscovite veins. In outcrops in the area adjacent to the basalt, arkosic metasedimentary rocks (subunit 4a), foliated granite (subunit 2e/3c) and perhaps tonalite gneiss (subunit 2a) are retrogressed to greenschist facies and locally contain a weak secondary foliation of similar orientation to that in the basalt. The retrogression is probably a Grenvillian effect and the secondary foliation may be also, although Grenvillian effects in the basement normally seem confined to faulting.

The interlayered subdivisions of the Seal Lake Group (subunit 11a) south of Marie Lake are folded and exhibit variably oriented bedding planes. East of the map area, the Seal Lake Group is deformed by northward-verging recumbent folds that are refolded about upright west-trending axial surfaces (Calon and Hibbs, 1980); similar complexity may be responsible for the diverse bedding attitudes south of Marie Lake.

North of Marie Lake, the Seal Lake Group red beds (subunit $11a^4$) are folded about gently plunging, west-trending periclines. The folds are moderately tight, locally with an overturned limb, and northward verging near Desolation Lake; they become increasingly open and upright northward. There is no axial-planar cleavage, but quartz veins are associated with buckling of the arenite and a sparry-carbonate matrix in some of the arenite may indicate a recrystallized cement.

The most significant Grenvillian faults trend east-northeasterly. Those to the southeast of Duck Bay are associated with quartz–carbonate veins. That through Marie Lake is probably a Grenvillian structure. A major reverse fault cuts the southern limb of the regional fold in the lobe southeast of the Michikamau Intrusion (Unit 10) and gives up to 2.5 km of dextral offset. Based on an average westerly dip of 50° for this limb of the regional fold and an approximate surface displacement of 2 km for this dip value, a dip-slip offset on the reverse fault in excess of 2.2 km is indicated, although the true slip vector is not known.

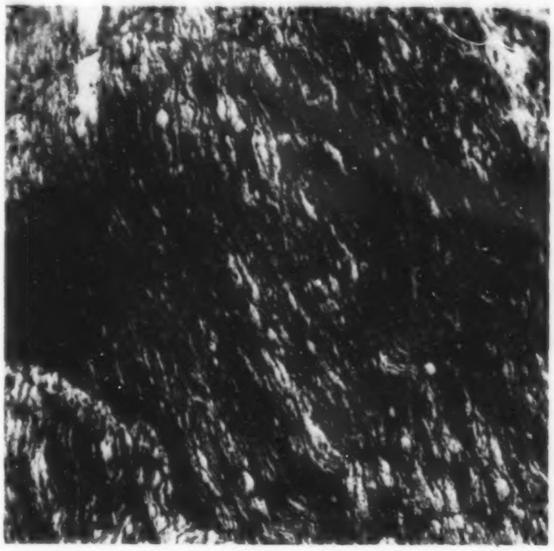


Plate 60. *Kink-banded, platey mylonite fabric containing scattered porphyroclastic relicts in quartz monzonite (subunit 9d). Photo GN81-CS30-16, locality G604, NTS 13L/3E, GR 9418.9811. Diameter of coin is 1.85 cm.*

Post-Grenvillian Faulting

The bounding subvertical fault system on the western margin of the Seal Lake Group (subunit 11a) is a post-Grenvillian structure. Where the red beds were moderately folded during the Grenville Orogeny they remained relatively unaffected by the subsequent downthrow of the red beds against the basement gneisses (Orma Domain) to the west. However, where these beds were only gently folded or still horizontal following the Grenville Orogeny, drag against the fault has rotated them into a vertical attitude. The attitude of the red beds in the gorge section, in which they are rotated into the vertical, implies a minimum vertical throw of 3 km on the fault system (graphic reconstruction; unpublished data).

The fault system has uplifted the basement over much of the map area, relative to the Seal Lake Group basin to the east, and exhumed, approximately, the basal Seal Lake Group erosion surface in the area west of the fault contact. Airphoto analysis suggests that the boundary is a swarm of small faults of several orientations rather than one major break. Most of the lineaments trend 165 to 180° or 140 to 155°.

The regional geological map of the Seal Lake Group suggests that several of these faults control the western edge of the Seal Lake Group basin as a set of half grabens. They appear not to be traceable into the Grenville Orogen and may be hinged near the major Grenvillian thrust front along the southern margin of the Grenville Front Tectonic Zone.

Miscellaneous

Many brittle structures are only tentatively correlated with specific events in the chronology or are unassigned.

Similar uncertainty applies to the low-grade (greenschist and sub-greenschist) metamorphic events in the map area, which are of both dynamic and static character.

Greenschist-facies mylonite zones that are of the same orientation as the post-Grenvillian fault system and have down-dip lineations in the basement gneiss and granitoid rocks, are possibly deeper level versions of this system, although they might be older, possibly Labradorian, structures instead. The best developed is the mylonite zone in the Naskaupi River between Orma and Marie lakes (Plate 60). Here, subunit 9d quartz monzonite is progressively more strongly foliated as the zone is approached and the foliation gradually rotates toward parallelism with the zone. The area of strongly sheared rock is about 60 m wide and is characterized by white quartz segregations and isoclinally interleaved green and red granitoid rock. All three rock types are fine grained, siliceous in appearance and very strongly platey, and have a strong, steeply pitching lineation.

REGIONAL IMPLICATIONS

ARCHEAN ROCKS

A major result of this study ensues from the follow-up geochronological determinations done at the Royal Ontario Museum (Nunn *et al.*, 1990). These data show that the extensive orthogneiss unit (Sail Lake intrusive suite, Unit 2) in the map area is Late Archean. The ages also confirm ideas, first noted by Stockwell (1963b) and more recently published in regional syntheses, that the eastern Churchill Province (Ashwal and Wooden, 1983; Ashwal *et al.*, 1986, 1988) or the equivalent part renamed as the Rae Province (Hoffman, 1987, 1988, 1989) contains large amounts of reworked Archean crust. Ashwal *et al.*, drew their conclusions from a study of the isotopic contribution of the basement to anorthositic massifs north and south of the Grenville Front—those to the north of the Grenville Front were contaminated by a much older (Archean) crust than those to the south of it. Hoffman (*op. cit.*) developed a regional synthesis of the Proterozoic growth of the Canadian Shield, in which correlation of this area of the eastern Churchill Province with other areas in the Trans-Hudson Orogen, now collectively termed the Rae Province, infers the presence of Archean rocks.

Studies on the eastern Churchill Province and adjacent areas of Labrador—Quebec, including the work of Nunn *et al.* (1990), contain other confirmations of Archean protoliths in the Rae Province (Ryan, 1990; Girard, 1990; Perreault and Hynes, 1990; Wares and Goutier, 1990), drawing partly on the regional studies of van der Leeden *et al.* (1990) and the geochronological data of Machado *et al.* (1989). However, whereas most of these workers imply Hudsonian tectonic and/or thermal reworking of the Archean rocks, a Hudsonian event is absent from the isotopic data given in Nunn *et al.* (1990) for the Orma Domain. This indicates that the Rae Province contains Archean rocks that range from strongly reworked (e.g., Ryan, 1990) to relatively unaffected (e.g., Dimroth, 1972, page 502; this report). The unreworked portions may range in size from map scale to larger regional augen, as the extent of areas like the Orma Domain is unknown.

The lack of Hudsonian/Early Proterozoic reworking in the Orma Domain allows a more detailed study of the Archean history in these rocks than might otherwise be possible. This study indicates that elsewhere the reworked areas may contain deformed belts of Archean supracrustal rocks, such as Unit 1, as well as Lower Proterozoic supracrustal units.

The Archean supracrustal unit would appear to represent a shallow to moderate depth shelf or platform environment. Thick sequences of greywacke and a bimodality of lithotypes, consisting of mafic volcanic rocks on the one hand and greywacke on the other, are missing. The unit does not, therefore, form a classical greenstone belt, despite the predominance of mafic volcanic rocks. A relatively shallow-water area fringing an emergent volcanic arc or oceanic island complex is indicated, although the succession could have been generated at a continental margin (perhaps at the edge of a depositional basin that, if preserved, might be a more typical greenstone belt) or in an aulacogen. Hence, the geotectonic and attendant metallogenic models that may be applicable in the map area, are numerous and varied.

The Sail Lake intrusive suite (Unit 2) comprises predominantly tonalitic and granodioritic orthogneiss. These compositions are typical of regional Archean plutonic gneisses (e.g., Rudnick and Taylor, 1986; Percival, 1987; Myers, 1987), and most particularly of those crustal levels just above the granulite facies (Park and Tarney, 1987). In addition, details from the Sail Lake intrusive suite indicate that it is, in part at least, a syntectonic plutonic suite and that successive phases were emplaced during a high-grade dynamothermal regime. Geochronological data (Nunn *et al.*, 1990) are compatible with syntectonic emplacement.

Several possibilities have been advanced for the Lower Proterozoic geotectonic environments of Archean rocks within the Rae Province. These include i), reworked former parts of the Nain and Superior cratons (e.g., Dimroth, 1972; Ryan, 1990); ii), rifted-off portions of these cratons produced during Early Proterozoic rifting or the basement to Lower Proterozoic supracrustal basins forming during crustal extension (Wardle and Bailey, 1981); iii), accreted terranes or microcontinent relicts attached to the Nain or Superior cratons during Early Proterozoic collision and orogenesis (e.g., Ryan, 1990); and iv), a separate Archean terrane trapped between the Superior and Nain cratons during Early Proterozoic continental assembly (Hoffman, 1990). These environments are not necessarily mutually exclusive.

The Ashuanipi Complex constitutes the easternmost part of the Superior Craton adjacent to the New Quebec Orogen to the west of the study area. It mainly consists of granulite-facies paragneiss and syntectonic tonalite (Percival, 1987). There is a broad similarity between the sequence of events recognized in parts of the Ashuanipi Complex (Percival, 1987; Mortensen and Percival, 1987) and that recognized in the Orma Domain, especially in terms of the age of their syntectonic tonalite batholiths. This similarity is strengthened if the gabbro–diorite–granite suite (Unit 3), which includes syenitic granitoid rocks, is Archean, rather than Early Proterozoic. In contrast, the geological history of the Hopedale Block, that part of the Nain craton adjacent to the Torngat Orogen to the east of the study area, appears significantly different in both age and lithological and tectonic development (Ermanovics *et al.*, 1982; Ermanovics, *in press*). These differences may be even greater if the proposed sinistral motion on the Torngat Orogen, produced during aggregation (transpressive docking) of the North Atlantic Craton (Nain Province) and the Rae Province (Watterson, 1978; Wardle *et al.*, 1990), is removed, possibly placing Archean crust having the considerably older isotopic signature of the Saglek area (Hurst *et al.*, 1975; Schiøtte *et al.*, 1989) nearer to the map area. Rejean Girard (personal communication, March, 1990) similarly considers that the Archean basement, 160 km north-northwest of the map area, has a greater affinity to the Superior Craton rather than to the Nain Craton. Farther north, near Ungava Bay, Perreault and Hynes (1990) note similar aeromagnetic signatures in the hinterland (western Kuujjuaq terrane on the western side of the Rae Province) to those in the Superior Craton basement to the New Quebec Orogen. On the eastern side of the Rae Province, also in the northern part of the peninsula, Korstgård *et al.* (1987) assign gneissic basement (to deformed Lower Proterozoic supracrustal sequences) to the Archean, but are equivocal as to whether or not it was of Nain Province parentage. Recent work in the same area suggests that at least some of the Lower Proterozoic-reworked Archean in the Rae Province is of eastern, i.e., Nain Province, affinity (Richard Wardle, personal communication, December, 1991). More detailed geological mapping, geochemistry and geochronology are required before a better understanding of the geotectonic environment of these Archean relicts is likely.

LOWER PROTEROZOIC ROCKS

The set of Labradorian structures associated with the North Pole Brook Intrusive Suite (Unit 9) in this area may be unique in the Trans-Labrador batholith. Synplutonic structures either are not present or have not been recorded as such in the rest of the batholith. The potential for their preservation exists only in northern parts of the Trans-Labrador batholith, north of, or in augen between, penetrative Grenvillian deformation. These structures indicate emplacement of the batholith under a regional stress system.

The Trans-Labrador batholith is posttectonic with respect to the major high-grade Labradorian dynamothermal metamorphism throughout central Labrador (Nunn *et al.*, 1985; Thomas *et al.*, 1985, 1986). Hence, structures in the batholith that do not fit typical Grenvillian trends should be looked at anew for protoclastic indicators. Given the overall orientation of the craton margin during the Labradorian, easterly or east-southeasterly compressive axes seem unlikely; however, speculatively, the north-northeasterly trending foliation might relate to a dextral transpressive component. Whether this would be combined with a predominant motion along the continental margin that is either overthrust or normal is critically dependent on whether the lineation pitches to the north-northeast or the south-southwest. In the map area, however, the fabrics of this age are predominantly planar and further investigation is needed.

Geochronological data (Nunn *et al.*, 1990) indicate early Middle Proterozoic lead loss in the orthogneiss. Syn- to post-Trans-Labrador batholith structures are probably too low in grade to effect such a lead loss. This raises the possibility that pre-Trans-Labrador batholith (early Labradorian) shear zones are present north of the batholith, but which have not been differentiated from older structures. Regionally, early Labradorian structures are not known from north of the Trans-Labrador batholith (Nunn *et al.*, 1985).

The Mackenzie Lake group (Unit 8) is tentatively regarded as a volcanosedimentary arc coeval with, and as relicts of a carapace to, the Trans-Labrador batholith (Nunn *et al.*, 1985). Similar ideas have been put forward for the Bruce River Group, 160 km east of the map area (Gower, 1990) and for the Blueberry Lake Group, 130 km southwest of the map area (Swinden *et al.*, 1991).

MIDDLE PROTEROZOIC ROCKS

Correlation of the patches of clastic sediment (subunit 11b) with the Seal Lake Group (subunit 11a), their very immature, near-unconformity nature, and their distribution within the map area indicate that the topography in the map area is close to that of an exhumed Middle Proterozoic erosion surface. A minimum relief of 140 m is indicated. The regional distribution of these occurrences suggests that the Seal Lake Group was once a blanket over an area of at least 23,000 km^2, an area that is twice the size of the main Seal Lake Group basin just east of the map area.

The exposures of the Seal Lake Group and its equivalents in the map area broadly show the same facies variation noted by Mann (1959) and Brummer and Mann (1961) for the main basin to the east. This variation consists of a transition from subaerial to shallow marine and from coarser to finer clastic rocks in a north to south direction. The limited number of current directions available for the map area and that to the south (varying from toward the southeast to toward the southwest) are consistent with a provenance to the north. These data indicate that the present outcrop-controlling fault system bounding many of the Seal Lake Group areas is post-depositional and not syn-depositional.

GRENVILLE DEFORMATION

The Grenville Front Tectonic Zone is defined in the map area as a zone of gradational Grenvillian tectonism ranging from the locus of no-longer-recognizable Grenvillian effect in the north to penetrative in the south. The zone shows a well-defined variation in early Grenvillian structures, which are ductile in Middle Proterozoic cover rocks and semi-brittle in the massive rocks of the basement to the Middle Proterozoic. This variation is similar to that noted by Rivers (1983) for the effects of Grenvillian deformation on Superior Province gneissic basement in contrast to that on the supracrustal cover constituting the Labrador Trough, 250 km west-southwest of the map area, and similar reasons are likely (Rivers, *op. cit.*, page 60). The Grenville Front is defined as the northern boundary of the Grenville Front Tectonic Zone. This definition is at odds with that commonly used elsewhere along the northern margin of the Grenville Province where the front itself is commonly given as a zone (Gower *et al.*, 1980; Rivers, 1983; Davidson, 1986a) or as the northernmost major shear zone or fault structure across which major structural, metamorphic, age or lithological differences occur (e.g., Rivers and Chown, 1986; Owen *et al.*, 1986; Davidson, 1986b). Most of these authors, however, recognize that Grenvillian structures or metamorphism locally still occur north of their 'front', and may even be widespread, albeit of low dynamothermal intensity.

PLEISTOCENE DEPOSITS

The zone of convergence of linear glacial features, predominantly fluting, that crosses the map area may represent the locus of preservation of a change in ice flow direction, perhaps due to adjustments in the significance of different dispersal centres (e.g., ice from the Kaniapiskau River area in Quebec, ca. 300 km west-northwest of the map area, and that from the mountains between Labrador City and Churchill Falls). The crosscutting fluting probably also relates to these adjustments.

The presence of a raised beach remnant near the present reservoir level, Low's (1896) record of other beaches in the Michikamau Lake area, and other occurrences of lacustrine and possible deltaic or fluvial sediment near the present reservoir level, indicate the presence of a proglacial lake. The beach relict lies above the upper level defined by strand lines associated with Lake Naskaupi, a proglacial lake ponded between the Torngat Mountains along the Quebec–Labrador watershed north of the map area and ice retreating northward down the George River north of Michikamau Lake, and is therefore earlier and/or unrelated to Lake Naskaupi. The raised beach remnant is also at a similar elevation to the present watershed between the George River and Michikamau Lake. As Michikamau Lake and much of the rest of the reservoir system sits on a plateau near the George River–Churchill River (Quebec–Labrador) watershed (Figure 3) and extends from the map area westward to Schefferville at the same height, this proglacial lake could have covered a large area of western Labrador (David Liverman, personal communication, June, 1991).

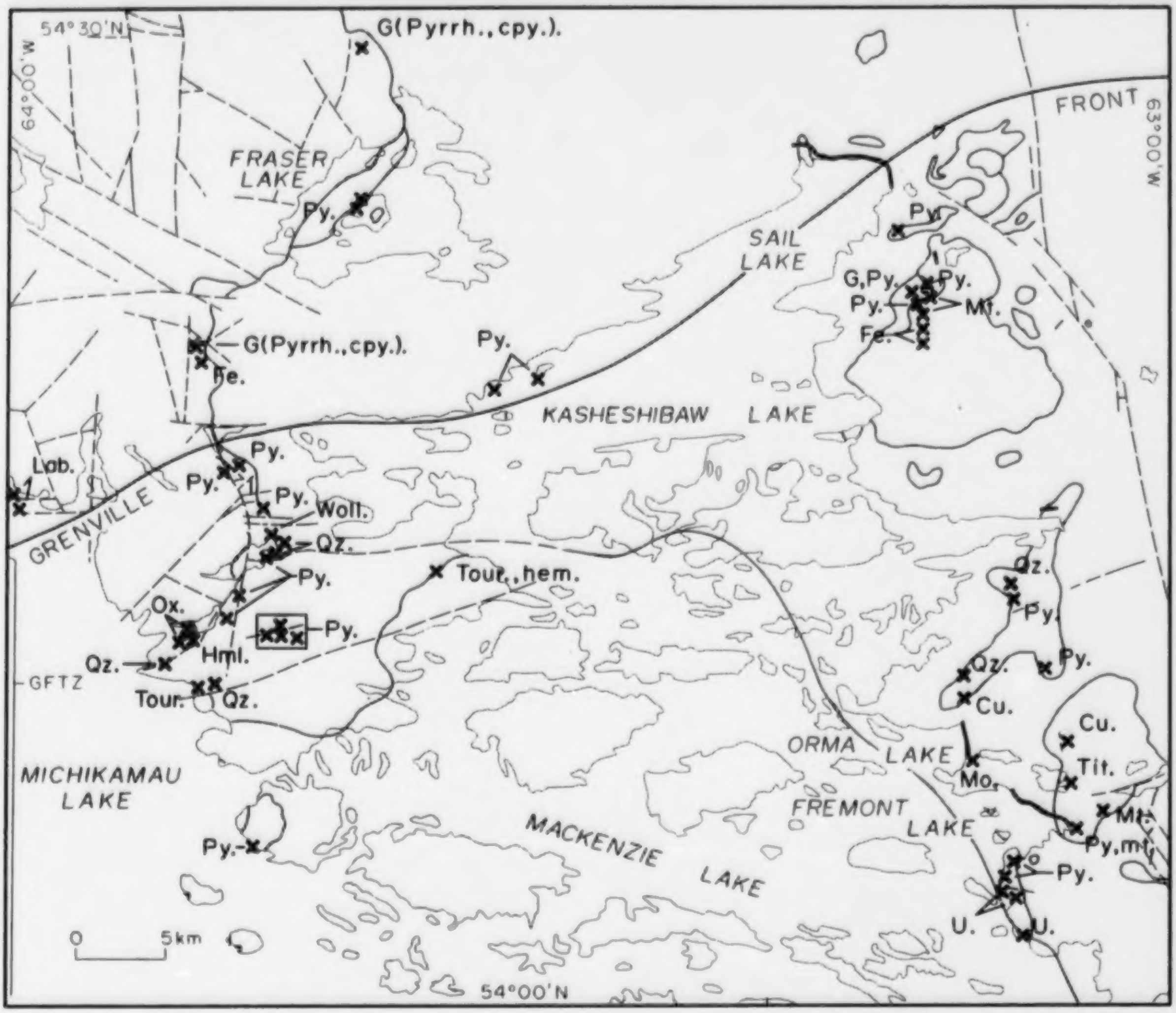
ECONOMIC GEOLOGY

MINERALIZATION

Geophysical exploration by Labrador Mining and Exploration Ltd. in the 1940's and 1950's consisted of airborne electromagnetic and scintillometer surveys. A number of minor, poorly defined anomalies were identified (Sutherland and Macpherson, 1957) but follow-up ground surveying failed to find a reason for the anomalies (Findlay, 1957; Sanderson and Jones, 1958). Similar work by Geoterrex and Barton and Barton (1971) obtained the same results, and slightly anomalous readings at the northern end of the airborne gamma-ray-spectrometry traverse by Darnley *et al.* (1972) were tentatively correlated, by them, with the granitoid rocks (Unit 9) occurring southeast of Michikamau Lake, and by Marten and Smyth (1975), with possible unconformities of supracrustal successions overlying granitoid rocks.

Mineral showings and occurrences of gossanous weathering are shown in Figure 16.

Widely scattered grains of pyrite occur in many of the rocks within the map area, including much of the Archean supracrustal rocks (subunits a, b, d, e, f and g of Unit 1) and the Petscapiskau Group (subunits a, c, e, f and ef of Unit 5), parts of the Sail Lake intrusive suite (subunits a, b and f of Unit 2), andesite (subdivision $8a^3$) and diabase dykes (subunit 12b). Pyrite in the rhyolite-porphyry conglomerate (subunit 5c) is found in the matrix and not in the felsic volcanic clasts. South of the map area, pyrite occurs in many of the phases of the North Pole Brook Intrusive Suite (Unit 9). Locally, pyrite is more concentrated and occurs disseminated in zones, patches and layers, which are generally brown- or rusty-weathering. These occurrences are usually parallel to the compositional layering present in the Archean supracrustal rocks (Unit 1) and the Petscapiskau Group (Unit 5) and have been noted from subunits 1a, d, f, g and 5e, f and ef psammite. Rarely, the linear, brown-weathering zones relate to tectonic features, e.g., sheared, fine-grained tonalite (subunit 2a) in tectonic contact with amphibolite (subunit 1a) 1 km north of Orma Lake is rusty-weathering and contains magnetite plus traces of pyrite and copper staining. The adjacent amphibolite contains a thin layer of pyritiferous siltstone or tuff (cf. subunit 1d). Also, rarely, pyrite-mineralized joints, fractures and alteration zones occur in quartz monzonite (subunit 9d equivalent) south of the map area (Nunn, 1981).


54°30'N
64°00'W
63°00'W
54°00'N
G(Pyrrh.,cpy.).
FRASER LAKE
Py.
SAIL LAKE
FRONT
Py.
G,Py.
Py.
Py.
Mt.
Fe.
G(Pyrrh.,cpy.).
Fe.
Py.
KASHESHIBAW LAKE
Lab.
Py.
Py.
Py.
Woll.
GRENVILLE
Qz.
Py.
Tour.,hem.
Ox.
Py.
Hml.
Qz.
GFTZ
Tour.
Qz.
Qz.
Py.
Qz.
Py.
Cu.
Cu.
MICHIKAMAU LAKE
ORMA LAKE
Mo.
Tit.
FREMONT LAKE
Mt.
Py,mt.
MACKENZIE LAKE
Py.
Py.
U.
U.
0
5km

LEGEND

Cpy.	*Chalcopyrite*
Cu.	*Copper stain*
Fe.	*Iron staining due to undetermined iron sulphides and/or oxides.*
G.	*Gossan*
Hem.	*Specular hematite*
Hml.	*Heavy mineral laminae*
Lab.	*Chatoyant labradorite*
Mo.	*Molybdenite*
Mt.	*Magnetite*
Ox.	*Fe-Ti oxides*
Py.	*Pyrite*
Pyrrh.	*Pyrrhotite*
Qz.	*High-silica quartzite*
Tit.	*Titanite*
Tour.	*Tourmaline*
U.	*High-CPS granite dykes*
Woll.	*Wollastonite*

Figure 16. *Mineral occurrences in the northeastern Smallwood Reservoir map area.* ✖ *Mineral occurrence*

Gossanous-looking layers and patches are not everywhere the result of sulphide mineralization. Some yellow- or rusty-weathering layers in subunits 1e paragneiss, 5e quartzite and 5e and 5ef psammite are related to concentrations of garnet, and brown-weathering patches in granodiorite gneiss (subunit 2b) and Petscapiskau Group interbedded pelite and psammite (subunit 5ef) and in the gneissic tonalite dykes (Unit 6) are associated with orthopyroxene in the aureole adjacent to the Michikamau Intrusion (Unit 10). Disseminated Fe oxides probably account for similar patches elsewhere in the orthogneiss (Unit 2) and in diorite (subunit 3b) along the road south-southwest of Proof Lake. It is not known why yellow-brown patches commonly occur with selvage material in metabasic pillow lava (subunit 5a).

Iron and Fe–Ti oxides are abundant throughout the Michikamau Intrusion (Unit 10). In the anorthosite (subunit 10c and subdivision $10b^3$), they are interstitial only, whereas in the troctolitic (subdivisions $10a^2$, $10b^1$ and $10b^2$) and gabbroic (subdivisions $10a^1$ and $10b^4$) rocks they are more abundant and commonly cumulus in origin. Localized sorting has concentrated them into oxide-rich layers in several places. At the west end of Magnetite Lake, the intrusion is in fault contact with the Petscapiskau Group and subdivision $10a^1$ is not present or is faulted out. The marginal zone subdivision $10a^2$ (pyroxene troctolite) contains 'layers and lenses up to 10 cm thick' that 'are very rich in oxides' … 'as well as zones up to a metre across that contain 30 to 50 percent magnetite plus ilmenite' (Emslie, 1970). The oxide-rich zones occur across a strike width of 300 m plus, and the magnetite within them contains 1.5 percent V_2O_3 (*ibid.*). In olivine gabbro (subdivision $10a^1$) near Contact Lake, rare, thin layers are rich in oxide minerals and, commonly, outcrops of leucogabbro (subdivision $10b^4$) contain 1- to 8-cm-thick oxide- or pyroxene-rich layers in 1- to 3-m cycles intercalated with anorthosite (*ibid.*).

Aside from disseminated oxides, olivine gabbro (subdivision $10a^2$) also contains scattered grains of pyrrhotite and chalcopyrite. Halfway between The Buttress and Hook Lake, these sulphides are abundant and define a 1.25 by 0.75 km area containing eight to ten patches of red-brown-weathering gossan. The gossans are equant to oval, up to 300 m long and occur near the contact between the Michikamau Intrusion (Unit 10) and Sail Lake intrusive suite orthogneiss (Unit 2). In this area, the Michikamau Intrusion contains Petscapiskau Group inclusions of pelitic paragneiss (subunit 5f), minor quartzite (subunit 5e) and possible granular metabasic rock (subunit 5a or 5b, or subdivision $10a^1$) along with granoblastic granitoid rock (subunit 2b). The inclusions are in pyroxene-hornfels facies. The sulphide mineralization is hosted mainly by the intrusion but also occurs in the Petscapiskau Group xenoliths. Sulphide forms up to 8 percent of the rock and occurs as extremely anhedral to blobby grains mostly up to 1.5 cm across. Pyrrhotite occurs in considerably greater amounts than chalcopyrite. The gossan-bearing area appears to have developed where several faults crosscut the intrusion–country-rock contact. Six samples from the gossan, which included host-rock olivine gabbro (subdivision $10a^2$) and country-rock inclusions (subunits 2b and 5f), were assayed; no unusual precious- or base-metal values were obtained.

Within the areas of gossan, rocks range from thoroughly altered to relatively unaltered. The most pristine-looking examples preserve a relict igneous texture and were derived from olivine leucogabbro. Plagioclase has a greasy to cloudy appearance and varies from anhedral to lathlike. Augite is black and fresh but olivine is altered to a soft, black amorphous material. Thoroughly altered examples are metamorphic textured rocks in which plagioclase forms pale, opaque-grey, equant polygonal grains and all ferromagnesian minerals are altered to unrecognizable amorphous substances.

Sulphide is disseminated throughout the fresher rock types in the gossans and consists of pyrrhotite and chalcopyrite, which occur singly or together. In more anorthositic rocks, they form 1 to 5 percent of groundmass minerals to plagioclase. In coarser rocks of more gabbroic composition, they occur in similar percentages but pyrrhotite may form irregular masses up to 3.5 cm across; chalcopyrite was noted up to 6 mm across. In the metamorphic-textured rocks, sulphides occur as small, intersertal grains and as larger groundmass crystals, up to 1 cm across, moulded on the 1- to 3-mm, polygonal plagioclase. They also occur as irregular grains in altered ferromagnesian seams, and, rarely, as globular forms in more coarsely crystalline patches.

Patches of coarser crystallization in the gabbroic rocks of the gossans include plagioclase, pyroxene, both sulphides, fresh black biotite and rare calcite, in which plagioclase reaches 8 mm, biotite 1 cm and sulphide 2 cm across. The biotite grew at the expense of fresh or amphibolitized pyroxene and perhaps olivine. The patches define a location fabric parallel to the layering in metabasic xenoliths or parallel to segregations and grain-size coarsening in the leucogabbro.

Opaque minerals, largely Fe oxide with Fe^{2+}–Ti oxide and minor sulphide, along with other heavy minerals, occur as thin laminae and lenses on foresets in quartzite (subunit 5e) south of Magnetite Lake. Magnetite concentrations and patches at centimetre to decimetre scale are present in quartz monzonite (subunit 9b) near Marie Lake and, south of the map area, occur in several phases of the North Pole Brook Intrusive Suite (e.g., equivalents of subunits 9a, 9b, 9d and 9e; Nunn, 1981).

Apatite is a common accessory in many basic rocks (subunits 1a, 1b, 1c, and throughout Unit 10). It is common in the orthogneiss (Unit 2) and, very rarely, occurs in densely disseminated lenticular patches in this unit. Titanite is a minor component (1 to 2 percent) of the mafic volcanic rocks (subunits 1a, 1b, 5a and 5b), of some metasedimentary supracrustal rocks (e.g., parts of subunit 1d), of the orthogneiss (Unit 2), in the coarsely crystalline patches in subunit 8a, and of granitoid rocks in the Trans-Labrador batholith. It is commonly an indicator of Trans-Labrador batholith phases (Nunn and Christopher, 1983), and at one locality between Orma and Marie lakes, it is more concentrated (locally up to 10 percent) and occurs as disseminated sphenoidal, magmatic grains up to 8 mm long (subunit 9d). Zircon is common in granitoid plutonic rocks (Units 2 and 9 and subunit 3c) and monazite occurs in subunit 2c orthogneiss. However, no large primary (igneous, marine) or secondary (metamorphic, metasomatic, hydrothermal) concentrations of apatite or monazite ± titanite (phosphate potential) or of zircon ± titanite (rare-earth potential) were found.

Tourmaline occurs as coarse, black rosettes on bedding planes in quartzite (subunit 5e) near the shore of Michikamau Lake. Also, it is present in the regionally metamorphosed pelite (subunit 5f) near the centre of the outcrop lobe of Petscapiskau Group, in pelitic laminae in the arenaceous rocks (subunit 5e) south of the Michikamau Intrusion, and as coarse porphyroblasts in pelitic layers in the metagreywacke (subunit 5d) at the east end of the lobe. Commercial extraction of boron from metamorphic rocks occurs in Kamchatka (quartz-tourmaline pegmatite) and Tibet (tourmaline granulite associated with iron formation) (Lyday, 1992).

Rare specular hematite is found in quartz veins in subunit 5d greywacke.

Molybdenite occurs in the granitic net-veins cutting ultramafic amphibolite (subunit 1c) just south of the Orma dyke. One crystal was 2 cm across. Subsequent visits to the locality failed to rediscover the mineralization.

A coarse-grained wollastonite–quartz rock occurs in the northeastern arm of Contact Lake. The assemblage is probably the result of contact metamorphism (Emslie, 1970). (Wollastonite is attracting increased attention as a potential short-fibre replacement for asbestos and for use in fibreglass products, and as a strengthener and whitener of rubber (O'Driscoll, 1990: Pugh, 1991).)

Anomalous readings on the scintillometer were obtained from several coarse-grained granitic pegmatites (Sail Lake intrusive suite, subunit 2g) on the lakeshore between Fremont Lake and Mackenzie Lake. Readings ranged from 1000 to 3000 total counts per second (cps) in the larger sheets and dykes; normal levels consisted of 90 ± 20 cps in granite dykes, 65 ± 25 cps in the tonalitic orthogneiss (subunit 2a) and 40 ± 25 cps in the metabasic rocks (subunits 1a and 1b). Slightly anomalous readings (50 percent above background) are common in the southeast of the map area, and locally are associated with subunit 4a arkose, the adjacent orthogneiss (subunit 2a) and, perhaps, a Seal Lake Group unconformity (Marten and Smyth, 1975; Nunn and Noel, 1982).

INDUSTRIAL AND CONSTRUCTION MATERIALS

Low (1896) recorded chatoyant feldspar in the anorthositic rocks on the shores of Michikamau Lake. Emslie (1970) noted that the iridescent plagioclase is common in anorthosite (subunit 10c) and less so in leucotroctolite (subdivision $10b^2$), and displays varying hues of blue, green and bronze.

Clean, white or light-grey quartzite and subarkosic arenite occur in Archean supracrustal rocks (subunit 1g), the Petscapiskau Group (subunit 5e) and the Seal Lake Group (subdivision $11a^3$). However, the feldspar content in subunit 5e and subdivision $11a^3$ significantly reduces the purity, and subunits 1g and 5e commonly contain pelitic, heavy-mineral and micaceous laminae. Both features reduce the silica potential of the quartzite.

The extensive system of large, easily accessible eskers in the map area is a potential major source of aggregate.

ECONOMIC POTENTIAL

Many of the units in the map area have potential for various types of mineralization, including and aside from those noted above, by virtue of their lithotypes or their possible environment of formation (Wardle, 1987; Swinden *et al.*, 1991).

Unit 1 is dominated by mafic volcanic, mafic hypabyssal, and various tuffaceous rocks, and is Late Archean. Areas of restricted sediment supply adjacent to volcanic edifices are prime targets for mineralization associated with submarine exhalative models. The unit could, however, be marginal to a greenstone belt. Typically, Archean greenstone belts are characterized by polymetallic sulphide occurrences and veins containing precious metals (e.g., Robert *et al.*, 1991), particularly where shear zones transect the greenstone sequence (e.g., Roberts, 1988). Fe, Cu and Ni (Naldrett, 1981) sulphides are associated with mafic–ultramafic volcanic rocks (cf. subunit 1a) and intrusions (cf. subunits 1b and 1c), which may be enriched in platinum-group-elements (PGE) (e.g., Macdonald, 1988) or chromite (e.g., Duke, 1988). Volcanogenic massive sulphides (VMS) occur with felsic volcanic rocks (cf. parts of subunit 1d), commonly at flow contacts (e.g., Franklin *et al.*, 1981), and sedimentary exhalative deposits (SEDEX) may be present in shale or pelite horizons (cf. subunit 1f), particularly those intercalated with volcanic rocks in Canadian greenstone sequences (e.g., Lydon, 1988). Gabbro sills in shale-rich sequences (cf. subunits 1b and 1e or 1f) might scavenge disseminated sulphide from the shale to form Ni–Cu mineralization in the gabbros, as in parts of the Labrador Trough (personal communication, H.S. Swinden, November, 1992).

Whether or not the Petscapiskau Group (Unit 5) is a temporal equivalent of the Archean supracrustal rocks (Unit 1), elements of the sequence are similar, and the unit has PGE (subunit 5b), VMS (subunit 5c) and SEDEX (subunits 5d and 5f) potential. The widespread occurrence of tourmaline in the pelitic facies of the Petscapiskau Group is suggestive of several genetic parageneses that include detrital, evaporite, authigenic–diagenetic and submarine exhalative sedimentary environments, as well as granite-related hydrothermal fluids (see, e.g., Appel and Garde, 1987, pages 22, 23). Where stratabound or concentrated in stratiform tourmalinites (the bedding plane laminae of tourmaline rosettes in subunit 5e?), these occurrences are increasingly being related to syngenetic SEDEX environments and, in places, have been associated with, or used as indicators in prospecting for, tungsten, tin and massive sulphide deposits (Taylor and Slack, 1984; Appel, 1988).

Appropriate models for both of the pelite-bearing supracrustal sequences (Units 1 and 5), therefore, include syngenetic shale-hosted massive sulphide deposits of SEDEX type (Pb–Zn) or, where contemporaneous volcanic activity is evident, Besshi type (Cu).

PGE targets occur in most gabbroic rocks (Wardle, 1987)–particularly layered ones (e.g., Macdonald, 1988) in which sulphide phases scavenge PGE, for example, the Bushveld Complex of South Africa (Naldrett and Cabri, 1976)–(cf. subunits 3a, 3b and 9a, Unit 10 and subdivision $11a^2$), and VMS potential occurs in acid volcanic rocks (cf. subdivision $8a^4$).

Granophile elements are concentrated in the later phases of many granitoid rocks and in acid volcanic and plutonic rocks generally (cf. subunits 1d, 2a to e, 2g, 3c, 5c, subdivision $8a^4$ and subunits 9b to 9h), and porphyry-type deposits are similarly spatially associated with granitoid intrusions (e.g., Strong, 1988).

Base metals, and gold and other precious metals occur in many geological environments. They are common in pyritiferous layers in paragneiss (cf. the Archean supracrustal rocks, Unit 1) and lower grade metasedimentary sequences (cf. the Petscapiskau Group, Unit 5), and in volcanic rocks. In the map area, volcanic rocks occur in greenstone and/or bimodal volcanic associations in Units 1 (subunits a, b and d) and 5 (subunits a, b and c), and as a relict of a continental arc in the Mackenzie Lake group (subunit 8a). Tectonometamorphic, igneous and hydrothermal veins are other potential hosts (e.g., Romberger, 1988), e.g., migmatitic felsic and quartz-rich veins at higher grade (cf. the Archean supracrustal rocks, the Sail Lake intrusive suite and some Petscapiskau Group aureole rocks; Units 1, 2 and 5) and quartz veins at lower grade (cf. the Petscapiskau Group and the Mackenzie Lake group, Units 5 and 8). These veins may also relate to faulting, e.g., the quartz–carbonate veins associated with faulting southeast of Duck Bay.

Several features of the geology of the map area (and the area to the south) indicate that much of this part of the Smallwood Reservoir lies close to an exhumed erosion surface, originally of Middle Proterozoic age. In eastern Labrador, alteration and base-metal mineralization occur near the unconformities between supracrustal rocks and a granitoid (Ryan, 1984; Wilton *et al.*, 1987) or felsic volcanic (Marten and Smyth, 1975) basement. The latter (*op. cit.*) includes specularite, fluorite, chalcopyrite, galena and chalcocite. In the map area, terrestrial clastic rocks and red beds of the metasedimentary rocks of uncertain affinity (subunit 4a), the Mackenzie Lake group (subdivisions $8b^1$ and $8b^2$) and the Seal Lake Group and its equivalents (subdivisions $11a^4$, $11b^1$, $11b^2$ and $11b^3$) overlie granitoid orthogneiss and plutonic rocks (Units 2 and 9, respectively). In Saskatchewan, the overlying supracrustal rocks contain tabular uranium reservoirs and roll-type deposits (Fischer, 1974) and, in both Saskatchewan (e.g., Marmont, 1988) and northern Australia (Marten and Smyth, 1975) shear zones beneath the unconformity host uranium mineralization. The Seal Lake Group (subunit 11a) unconformity was studied for its uranium potential east of the map area by Marten and Smyth (1975) who noted evidence of detrital uranium-bearing minerals in the Seal Lake Group (A. Beavan, personal communication to Marten and Smyth, *ibid.* page 111), abundant anomalies (recorded by Robinson, 1956, BRINEX, unpublished data; Baragar, 1969 and Marten, 1975), and seams of pitchblende along the unconformity (Robinson, 1956; Marten and Smyth, *op. cit.*).

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APPENDIX I

RADIOMETRIC AGE DATA

1. Quartz syenite (subunit 9e), North Pole Brook Intrusive Suite
Sample NN81-432
Data from Brooks, 1983

ANALYTICAL TECHNIQUES

Uranium – Lead

Zircons were separated using standard Wilfley Table and Franz Magnetic treatments. The zircon samples were decomposed and the appropriate uranium and lead fractions obtained using the techniques developed by Krogh (1973). Blank levels are about 2×10^{-9} g total Pb, or less, and 1×10^{-9} g total U, or less. These blank levels are essentially insignificant for the sample sizes used (15 to 25 mg).

For the lead analyses, internal precision for $^{207}Pb/^{206}Pb$ ratios is typically of the order of 0.1 percent (95 percent confidence-level) or better; $^{204}Pb/^{206}Pb$ ratios are somewhat less precise, depending on the amount of nonradiogenic lead in the sample. With all factors considered, the uncertainty in the finally corrected radiogenic lead $^{207}Pb/^{206}Pb$ ratios is estimated to be better than 1 percent.

Isotopic fractionation and systematic errors were monitored using analyses of the NBS lead standards (National Bureau of Standards, SRM 981, 982, 983). These analyses indicate no major systematic errors and are consistent with the uncertainties quoted above. The U–Pb and Pb–Pb ages were calculated using the new decay constants of uranium: $(^{235}U) = 9.8485 \times 10^{-10}\ y^{-1}$, and $(^{238}U) = 1.55125 \times 10^{-10}\ y^{-1}$; the natural $^{238}U/^{235}U$ ratio was assumed to be 137.88. The common-lead corrections in the samples were made by proportioning the nonradiogenic lead into blank lead and original common lead. For the blank, the assumed values were 204:206:207:208 = 1.0:18.6:15.8:39.0. For original common lead, the composition of 1500-million-year-old single-stage model lead ratios of 1.00:16.33:15.58:36.30 were used, based on the parameters of Kanasewich (1968). For this analysis the results are insensitive to reasonable variations in these parameters.

RESULTS

Quartz Syenite

One large sample (NN81-432), representing a medium-grained, potassium-feldspar-megacrystic phase of the North Pole Brook Intrusive Suite, was separated with a poor yield in zircons. All zircons were typically equant and euhedral, with complete gradation from small (<200 mesh) to large (>100 mesh) crystals. The population was split into six magnetic fractions of between 5 to 10 mgs each, and the least magnetic (1°, 2° and 3°) fractions were hand picked and analyzed. The main difference between the three populations is that with increasing degree of magnetism, the zircons show more cracks, iron staining, milky colours and a generally 'dirty' appearance.

The analytical results are given in Table A1.1. and plotted on the U–Pb concordia diagram (Figure A1.1). Examination of this diagram and the Pb–Pb ages in Table A1.1. shows that the most magnetic fraction (3°) is discordant with respect to the other fractions. It also has the highest U content. Consequently, it is not possible to obtain a three-point U–Pb concordia age for this sample. The most reliable estimate comes from the 1° and 2° samples and corresponds to an upper concordia intersection of 1576 Ma (the lower intersection is 31 Ma). The 1576 Ma estimate is in good agreement with the Pb–Pb ages of 1573 and 1571 Ma for these fractions. A conservative error in the concordia age is not more than 10 Ma. The age of crystallization is hence estimated at 1576 ± 10 Ma.

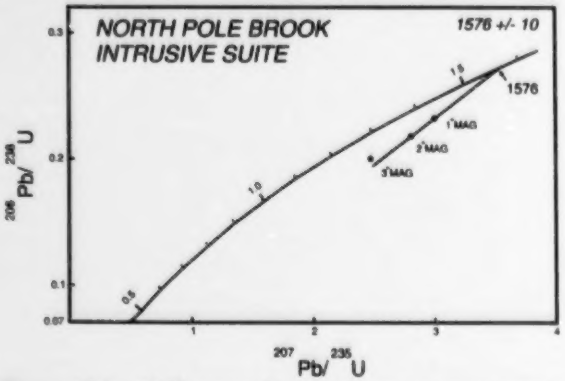

Figure A1.1. *U-Pb concordia plot of quartz syenite; sample NN81-432, locality N149, NTS 13L/4E, GR 6343.0072, subunit 9e.*

Table A1.1. Analytical results for the quartz syenite (NN81-432)

Sample	Concentration		Atomic Ratios				
	U (PPM)	Pb (PPM)	$\frac{^{204}Pb}{^{206}Pb}$	$\frac{^{207}Pb}{^{206}Pb}$	$\frac{^{208}Pb}{^{206}Pb}$	$\frac{^{206}Pb}{^{238}U}$	$\frac{^{207}Pb}{^{235}U}$
1° Magnetic	415.4	118.6	0.00137	0.11615 (1573)	0.26628	0.2351	3.1532
2° Magnetic	615.5	163.4	0.00131	0.11530 (1571)	0.26432	0.2190	2.9349
3° Magnetic	700.6	179.0	0.00201	0.12132 (1497)	0.29151	0.2012	2.5918

2. Hypabyssal andesite (subdivision 8a¹), Mackenzie Lake group
Sample GN81-791B
Data from Krogh (1985)

ANALYTICAL TECHNIQUES

Uranium–Lead

Zircons were separated and prepared using the analytical techniques described in Krogh (1973, 1982).

RESULTS

Andesite

This rock contains a relatively small amount of mostly small (<200 mesh) zircons. All sizes of the least magnetic grains were combined; two samples, both with a high degree of integrity, were analyzed after abrasion and selection of crack-free components. A third fraction from the same magnetic splits, but with cracks present, was analyzed to indicate the discordia pattern. The three data points combined (the two good points are coincident at 2 percent discordant) give an age of 1651$^{+2.8}_{-2.6}$ Ma, and a lower intercept of 617 Ma (Figure A1.2). The results are shown in Table A1.2.

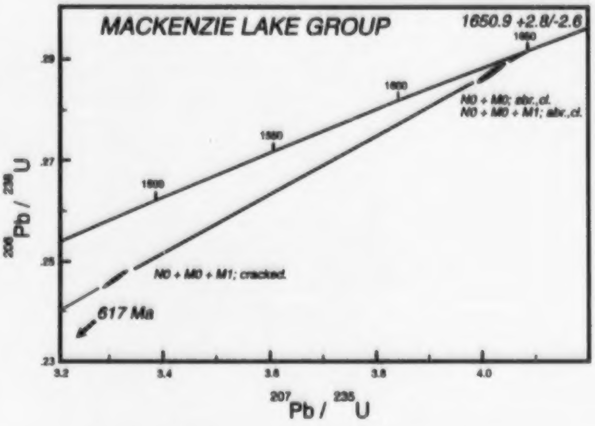

Figure A1.2. *U-Pb concordia plot of hypabyssal andesite; sample GN81-791B, locality G598c, NTS 13L/4W, GR 4865.9233, subdivision 8a¹.*

Table A1.2. Analytical results for the hypabyssal andesite (GN81-791B)

	Weight	Concentration			Atomic Ratios							Apparent Age (Ma)		
Fraction	Sample (μg)	U (ppm)	Pb* (ppm)	Common Pb* (nm/g)	$\frac{^{208}Pb^*}{^{204}Pb}$	$\frac{^{207}Pb^*}{^{204}Pb}$	$\frac{^{206}Pb^*}{^{204}Pb}$	$\frac{^{208}Pb^{**}}{^{206}Pb}$	$\frac{^{207}Pb^{**}}{^{206}Pb}$	$\frac{^{206}Pb^{**}}{^{238}U}$	$\frac{^{207}Pb^{**}}{^{235}U}$	$\frac{^{206}Pb}{^{238}U}$	$\frac{^{207}Pb}{^{235}U}$	$\frac{^{207}Pb}{^{206}Pb}$
NO+MO, all sizes, cl., abr.	163	102.6	30.7	2.87	434.4	449.1	4302.9	9.301	0.101	0.288	4.015	1630	1637	1646
NO+MO+M1, all sizes, cl., abr.	114	112.3	38.4	1.11	3370.2	1241.7	12144.0	0.275	0.101	0.288	4.012	1630	1637	1645
NO+MO+M1, all sizes, cl.	44	257.0	78.2	0.26	309.1	114.2	1029.8	0.270	9.748	0.246	3.313	1420	1484	1576

Mineral analyzed = zircon
N,M = non-magnetic and magnetic at the indicated angle of side tilt (0° or 1°) on a Franz Isodynamics Separator.
Grain-size range = 70−100−200−325 mesh; cl. = clear; abr. = abraded (Krogh, 1982); nm/g = nanomoles per gram.
* Fractionation and blank corrected.
** Fractionation, blank and common Pb corrected (Stacey and Kramers, 1975).
Analytical procedures outlined in Krogh (1973, 1982).
Decay constants for ^{238}U (1.55125×10^{-10} yr^{-1}) and ^{235}U (9.8485×10^{-10} yr^{-1}) are those recommended by Jaffey *et al.* (1971).

APPENDIX 2

NOTES

Thin section control of assemblage in italics.

In hand specimen, identification of cordierite was increasingly difficult with greater distance from the contact as it gradually loses its bluish or greasy, dark-grey cast: identification of the presence and relative proportions of quartz, feldspars and cordierite was problematic. Similar difficulty was encountered in some thin sections.

Assemblages are followed by the number of faults (F) separating the assemblage locality from the Michikamau Intrusion (Unit 10), and the distance, in metres, from the contact. All faults appear to have shortened the distance between these assemblages and the intrusion (by unknown amounts) given a shallowly westward-dipping contact (Emslie, 1970).

Minerals listed in decreasing order of abundance.

Abbreviations

? unknown mineral, or expresses uncertainty about the data immediately following the question mark.

→ mineral reaction; mineral in parentheses no longer present.

Minerals

Actin.	actinolite	Granoph.	granophyre	Py.	pyrite
Amph.	amphibole	Gt.	garnet	Qz.	quartz
And.	andalusite	Hb.	hornblende	Qzofels.	quartz and feldspar
Aug.	augite	Ksp.	potassium feldspar	Sapph.	sapphirine
Bio.	biotite	Micro.	microcline	Serp.	serpentine
Carb.	carbonate	Musc.	muscovite	Sill.	sillimanite
Chl.	chlorite	Ol.	olivine	Sp.	spinel
Cord.	cordierite	Op.	opaque mineral	Ss.	saussuritized feldspar
Cpx.	clinopyroxene	Opx.	orthopyroxene	Tit.	titanite
Diop.	diopside	Pinn.	pinnite	Tour.	tourmaline
Epid.	epidote	Plag.	plagioclase	Trem.	tremolite
Fels.	feldspar	Preh.	prehnite	Woll.	wollastonite
Femg.	ferromagnesian mineral	Px.	pyroxene		
2 mica	muscovite and biotite	2 fels	plagioclase and potassium feldspar	2 px	clinopyroxene and orthopyroxene

Colours

b.	brown	r-b.	red-brown	gn.	green	b-gn.	blue-green

Superscripts

1 A bladed or acicular, semi-translucent or grey mineral.
2 Intergrowth of preceding minerals.
3 Relict grey mineral inclusions in cordierite, commonly sheathed in fibrolite and overprinted by prismatic sillimanite; probably andalusite.
4 Polygonal, colourless, low birefringent, relief > cordierite and feldspar.
5 Unknown brown to greenish-grey reaction rim between hornblende/clinopyroxene-rich matrix and polygonized aggregates of plagioclase.
6 Pseudomorphs, probably of olivine.
7 Patches of coarse crystallization, commonly vug-like and/or with drusy texture.
8 Reported in Emslie (1970).
9 In the centre of the lobe, distances from both Unit 9 (TLB) and Unit 10 (M.I.) seem too great to account for the porphyroblastic mineralogy; an underlying cupola or stock of Unit 9 is a possibility.
10 Regional assemblage(s) (see last column) plus porphyroblastic overprinting by the given minerals.
11 Replacement and locally porphyroblastic minerals; may have formed as outermost aureole, or closer to the intrusions under waning temperatures, or during later low-grade metamorphic events.
12 Regional assemblages are from southern areas (the lobe) unless designated north of Contact Lake (N).

Table A2. Contact metamorphic mineral assemblages associated with the Elsonian Michikamau Intrusion

Unit/ Subunit	Rock type	Inclusions in Unit 10	Contact Column 1	≈450 m Column 2	≈950 m Column 3
5f	Pelite and semipelite	Cord.-opx.-?sp.	Cord.-plag.-sill.-and.; 100 Cord.-sill.-qzofels. ± gt.; 200-400 *Ksp.-cord.-sp.-epid.-sill.;* 100 *Cord.-sill.-op.-?*[3]; 300-400 *Cord.-qzofels.-sill.-op.-sp.;* 200 *Sill.-plag.-cord.-op.-qz.-sp.;* 200 *Cord.-sill.-plag.-op.-qz.-granoph.-sp.;* 200 *Plag.-cord.-opx.-op.-?*[4]; F, >200 *Cord.-opx.-op.-plag.;* F, >200 Qzofels.-hb.-opx.; 100 Cord.-opx.; 200 Qzofels.-cord.-and.; 200,300 Qzofels.-bio.-and.; 300,400 Qzofels.-sill.; 200	*Cord.-Ksp.-gt.-qz.-r-b.bio.-sill.-pinn.-op.-sp.-epid.;* 800 *Cord.-plag.-sill.-gt.-qz.-sp.-r-b.bio.-micro.-op.-epid.-sapph.;* 500 *Plag.-b.bio.-cord.-sp.-op.-opx. ± gt.;* 500 Qzofels.-gt.-cord.-?opx.-?sill.; 600 Cord.-fels. ± qz.; F, >300-700 *Ksp.-cord.-and.-plag.-r-b.bio.-op.-sill.-qz.-py.;* 800 Plag.-qz.-bio.-femg.; 500+ Cord.-qzofels.-and.; ?F, >400 Cord.-qzofels.; ?F, >500	Cord.-qzofels.-gt.-?sill.; 1000 Bio.-qzofels.-?sill.-b.spots; 1100 *Qz.-plag.-cord.-r-b.bio.-tour.-and.-op.-sill.;* 1000 Qzofels.-and.-gt. ± ?cord.; 900-1100 Cord.-and.-qzofels.; 1300
	Migmatization/sweating		Qz. ± fels. ± gt.; 200 *Qz.-granoph.-cord.-plag.-op.-sill.;* 200 *Plag. ± opx.;* F, >200		
5e	Psammite		*Cord.-qz.-gt.-op.-sp.-r-b.bio;* 100,400 *Qzofels.-b.bio-op.;* F, >200 *Qzofels.-b.bio.-cord.-gt.-op.;* F, >100	*Qz.-opx.-plag.-Ksp.-b.bio.-op.;* 500 Qzofels.-cord.-gt.; F, >700 *Plag.-qz.-opx.-micro.-r-b.bio.-op.;* 900	
	Calcareous psammite		*Qz.-trem.-cord.-op.;* F, >100		
	Quartzite	Qz.-opx.-?[1] Qz.-cord.	Qz.-gt.-op.; F, >100 Qz.-femg.-op.; F, >100		Qz.-gt.-op.; 1300
	Calcareous quartzite		Qz.-diop.-gt.-op.; F, >100		
	Veins/sweating				Qz.-gt.; 1300
5c	Metaconglomerate				
5b	Metagabbro		Plag.-hb.-cpx.-corona[5] ± gt. ± ?diop.; 200+		
5a	Metabasic volcanic rocks		?2px. granulite; 100	Hb.-diop.-plag. ± gt.; F, >400 Hb.-plag.-op.; 800 Hb.-plag.; 600-800, F, >400	*Hb.-plag.;* F, > 800,900,1000 *Hb.-plag.-op.-qz.;* 2F, >900 *Hb.-plag.-op.-bio.;* 2F, >1000 *Hb.-plag.-qz.-op.+tit.-qz.-epid.* patches[7]; 1000
	Migmatization/sweating		Plag.-opx. ± qz.; F, >200 Diop.gt. ± hb.; F, >300	Qz. ± plag.; F, >400 Hb.-diop.; F, >400	*Hb.-plag.-tit.-op.-qz.-?cpx.+qz.-tit.* patches[7]; >800 Qz.
5a/b/ 10a[1]	Metabasic rock	Plag.-cpx. Diop.-aug.-plag.	*Plag.-aug.-ol.-b.hb.-op.;* 300 Plag.-aug. ± ol.; ≤300 *Plag.-b.hb.-cpx.op. clots*[2]*-op.+(chl.-carb.-epid.*[6]*);* 300		
2	Orthogneiss	Fels.-qz.	Plag.-qz.-femg.-opx.-op.; 100 Fels.-qz.-opx.-r-b. bio.; 200	Fels.-qz.-bio.-opx.-op. ± femg.; 400-1100 *Plag.-qz.-Ksp.-r-b.bio.-op.-?opx.-epid.;* 800 Plag.-qz. ± Ksp.-bio.-opx.; 800	
	Mafic layers and inclusions		*Cpx.-hb.-plag.-op.-bio.+hb.-epid.-?cpx.* patches[7]; 200		
8a	Andesite				
8b	Metasediment	Plag.-cpx.op. clots[2]			
	Veins/sweating	Plag.-px.-op.-qz.			

Table A2. (continued)

Unit/ Subunit	≈1350 m Column 4	≈2150 m Column 5	≈3000 m Column 6[9]	Retrograde minerals[11]	Regional assemblages[12]
5f	Cord.-and.-qzofels.; 1400-1500 *Bio.-plag.-Ksp.-and.-cord.-op.-tour.-gt.*; 2100 Qzofels.-and.-gt.-hb.; 1500	Qzofels.-2 mica-and.; 2900 *Gn.bio.-and.-?pinn.-tour.-op.* ± *gt.*; 2200 (sill.) and.; 2200	*Regional*[10] *+b.bio.*; 2F, 3600 MI/6000 TLB	Chl., musc., pinn., layered and amorphous mineraloids	*Gn.bio.-musc.-chl.* schist Chl.-musc. schist Bio.-chl. schist *Qz.-musc.-chl.-op.* schist
	Qz. ± gt.				Qz. ± fels.
5e	*Qz.-2 fels.-op.-epid.*; 1600, 1700 *Qz.-Ksp.-plag.-r-b.bio.-cord.-op.*; F, >1400	*Qz.-fels.-gn.bio.-amph.-op.-tit.-tour.-gt.*; 2200		Chl., epid., op., carb., musc., gn.bio.	
		Qz.-fels.-gn.bio.-tour.-op.; 2200		Musc., chl. Chl., musc.	
	Woll.-qz.[8]; 1500				
5c		Qz.-chl. and/or bio.-epid.-op.; 2F, >2500-3500 *Qzofels.-gn.bio.-op.*; 2F, >2600 (groundmass)	*Regional*[10] *+b-gn.hb.-epid.*; 3F, 6600 MI/3500 TLB Glassy groundmass; 2F, 3600 MI/6000 TLB	Chl., musc.	*Qzofelz.-musc.-gn.bio.-epid.* *Qzofels.-gn.bio.-musc.-chl.* *Qzofels.-chl.-op.-epid.* *Qz.-b.bio.-chl.-plag.-op.-musc.-epid.*
5b		*Qzofels.-musc.-op.-gn.bio.*; 2F, >2600 (clasts)		Chl.	Plag.-hb. ± gt.; N
5a	Hb.-plag. ± op.; 2F, > 1600,1800,2000			Epid., chl., carb., qz., musc., preh.	Hb.-plag. Plag.-amph.-epid. Diop.-gt.-hb.-plag.-qz.; N Gt.-hb.-plag.-qz.-opx.; N
5a/b/ 10a[1]				Chl., epid., carb., serp.	
2	2 fels.-qz.-bio. and/or musc.-b.spots; 1900-2100 Fels.-qz.-bio.-hb.; 1500, 1600	2 fels.-qz.-bio.- and/or musc.; 2400		Chl., musc., ss., epid., ?gn.bio.	Qzofels.-bio. ± hb. ± tit.-op.; N
		Gn.hb.-plag.-qz.rims, Actin.-epid.-qz.cores; 2700			
8a			*Amph.-preh.-epid.-?carb.*; F, >3000		
8b					

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